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THE PRE-RICHMOND UNCONFORMITY IN THE MISSISSIPPI VALLEY

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Ulrich and Schuchert[1] have called attention to the widespread emergence of the land in the interior of North America at the beginning of the Richmond stage of later Ordovician time, and the resubmergence of the same during the later portion of the same stage. This epoch in the geologic history of the North American continent is one which has usually been overlooked, but which, nevertheless, is of vast importance.

During mid-Ordovician time a great interior sea reached westward from Appalachia to the Rocky Mountain region. In this sea the Trenton limestone of New York, New Jersey, and Pennsylvania was being deposited, as well as the equivalents of this formation farther west, the Galena limestone of Wisconsin, Minnesota, northern Illinois, and Iowa, and the Kimmswick limestone of southern Illinois and southern Missouri. In the Big Horn Mountains of Wyoming the greater portion of the Big Horn limestone is also contemporaneous in age with the Trenton and Kimmswick limestones of the east. In the regions between these outcropping areas, now occupied by younger formations, limestones of similar age are doubtless buried beneath the younger strata.

Following mid-Ordovician or Mohawkian time, this great interior sea became much contracted, so that the beds of Utica and Lorraine

[1] E. O. Ulrich and Charles Schuchert, "Paleozoic Seas and Barriers in Eastern North America," *Report of the New York Paleontologist for 1901*, pp. 645, 646.

age, the two lower divisions of the upper Ordovician or Cincinnatian period, are restricted, so far as known, chiefly to the region lying east of the Cincinnati arch. During Richmond time, however, the interior sea again transgressed to the west and north until it again stretched from Appalachia to the Rocky Mountain region. The evidence for this withdrawal and readvance of the interior sea in post-Trenton times is both paleontologic and stratigraphic in nature, and some portions of this evidence will be considered in the following pages.

In the earlier work of the geologists of Illinois, Wisconsin, Iowa, and Missouri, no important subdivisions of the Cincinnatian, or "Hudson River" as it was usually termed, were recognized, and consequently, in the absence of any conspicuous stratigraphic unconformity, the sequence from the Trenton limestone or its equivalent to the close of the Ordovician seemed to be complete. More recent critical investigation of the Cincinnatian faunas in the Ohio Valley has demonstrated that at least three distinct faunal divisions, the Utica, Lorraine, and Richmond, are included in the period, and the only one of these which has been recognized anywhere in Illinois and Wisconsin or in the region to the west belongs to the highest or Richmond division of the Cincinnatian period.

The fauna of the Richmond in the Mississippi Valley exhibits two facies, or perhaps more properly two sub-stages, which are more or less different in character. In the Richmond fauna proper, as typified by the fauna of the beds at Richmond Indiana, the brachiopod *Rhynchotrema capax* is by far the most characteristic species, and beds bearing this same fauna occur at many localities in Illinois, Wisconsin, and Missouri.

In northwestern Illinois and eastern Iowa, however, a second faunal facies occurs in the Maquoketa shales, where an important element in the fauna consists of a large number of small pelecypod shells belonging to the genera *Cleidophorus* and *Ctenodonta*, *Cleidophorus neglectus* being perhaps the most conspicuous species. The fauna of the Maquoketa beds, however, is not uniform throughout, and faunules are frequently present in Iowa and elsewhere containing examples of *Rhynchotrema capax* and other members of the typical Richmond fauna. At points farther south in the Mississippi Valley, in Jefferson County, Missouri, and Monroe County, Illinois,

the typical Maquoketa fauna with an abundance of *Cleidophorus neglectus* occurs in certain shales immediately superjacent to a limestone bearing the typical *Rhynchotrema capax* fauna of the Richmond, so that the Maquoketa is shown to be at least as young or even younger than the Richmond proper.

The faunal break in passing from the subjacent Trenton horizon to the superjacent Richmond or Maquoketa is sharp, there being little or nothing in common between the lower and the upper faunas, and the unconformity suggested by this faunal change is confirmed by an actual physical unconformity between the strata over a large area.

The locality where the physical unconformity is most conspicuously shown is in southern Calhoun County, Illinois, on Madison Creek south of Batchtown. At this point the typical Richmond with its *Rhynchotrema capax* fauna does not occur, the section being as follows:

1. *Maquoketa shale*, 75 feet in thickness. In the upper part this formation is a very fine-grained clay shale of a light greenish color, weathering to an olive green, some layers containing an abundance of graptolites. In its lower beds the formation becomes yellower in color and more gritty in texture, and in the lowest six or eight feet are several harder and still more gritty beds from one to three inches in thickness which stand out upon weathered banks by reason of their greater resistance. In these harder layers fossils rarely occur, the only two genera observed being *Leptobolus* and *Cleidophorus*. At the very base of the formation is a granular bed one inch or less in thickness which is filled with examples of *Cleidophorus neglectus*, besides several species of *Ctenodonta*, a small *Orthoceras*, several gastropod shells, and an occasional fragment of a trilobite.

2. *Red residuary clay*, four to ten inches in thickness, in which are imbedded numerous angular, fossiliferous cherts.

3. *Kimmswick limestone*, ±50 feet in thickness. This is a light-colored, highly fossiliferous, crystalline limestone of Trenton age. Its superior surface is very uneven beneath the residuary red clay that rests upon it.

The unconformity in this section is represented by the red residuary clay lying between the Kimmswick limestone and the Maquo-

keta formation. This material can only have been formed as the product of the subaerial decay of rocks, doubtless of limestones which originally were present above the present uppermost layer of the Kimmswick limestone. The deposit is similar in every respect to the red residuary clays which are so uniformly present in southern Missouri and elsewhere beyond the glacial border, sometimes many feet in thickness, and containing the resistant cherts which were originally included in the limestone formations now destroyed by

FIG 1.—Unconformity between Kimmswick limestone and Maquoketa shale near Batchtown, Calhoun Co., Ill. A, Kimmswick limestone; B, Red residuary clay; C, Maquoketa shale.

weathering. The presence of this residuary clay in the section is conclusive evidence of the existence of an area of dry land in the Mississippi Valley region, probably of long duration, between the period of deposition of the subjacent Kimmswick limestone and the superjacent Maquoketa shale. The presence of this bed at this point is perhaps only local, but the remarkable fact is that any of this residuary clay should have been preserved actually *in situ*. With the readvance of the sea it would seem that the wave action would have washed the underlying hard rocks clean of their covering, and indeed the few inches here present may be only the remnant of a former

much thicker bed. That these few inches of clay, however, are in the main actually undisturbed is quite apparent, only the uppermost layer, a fraction of an inch in thickness, showing evidence of having been reworked by the waves, by reason of the mingling of Maquoketa fossils.

In passing southward this stratigraphic interval is next encountered in St. Louis and Jefferson Counties, Missouri, and in Monroe County, Illinois. In none of this more southern area has such a striking instance of physical unconformity been observed as that near Batchtown, but the unconformity is none the less distinctly shown. The section in this region is slightly different from the Calhoun County section, by reason of the presence of the true Richmond with its *Rhynchotrema capax* fauna, and may be somewhat generalized as follows:

1. *Burlington limestone* and *Kinderhook beds*, whose differentiation is not of importance in this place, resting unconformably upon the Maquoketa shale.

2. *Maquoketa shale*, 4 to 30 feet in thickness, often with abundant graptolites in the higher beds, and with the typical *Cleidophorus neglectus* fauna at the base. This formation exhibits much variation in different vertical sections in the region, but it always contains the typical Maquoketa fauna.

3. *Richmond limestone*, ±2 feet in thickness. This is a hard, more or less impure limestone, somewhat darker colored than that below. It is abundantly fossiliferous, the most conspicuous species being *Rhynchotrema capax*. This bed is remarkably uniform in character, both lithologically and faunally, throughout this region of outcrop.

4. *Kimmswick limestone*, ±50 feet in thickness. The outcrop of this limestone along the Mississippi River in Jefferson County constitutes the typical expression of the formation. It is remarkably uniform in all of its characters, with the same formation in Calhoun County.

In any single vertical section in this region the physical unconformity between the Kimmswick limestone and the Richmond bed is not conspicuously exhibited, although the faunal change is sudden and complete. In following the contact from the section at the railroad cut one mile south of Kimmswick, however, to the quarry at Glen Park, and then in the sections of the river bluffs to an aban-

doned quarry one-half mile farther down stream, a total distance of from two and one half to three miles, it is clearly seen that the Richmond rests upon higher and higher strata of the Kimmswick limestone. At the northern end of this section the uppermost bed of the Kimmswick, immediately beneath the Richmond, is characterized by a fauna in which bryozoans are the most conspicuous element. At Glen Park the upper bed of the Kimmswick is a higher stratum than that farther north, and the fauna contains more trilobites and pelecypods. Farther south a still higher bed of the Kimmswick limestone, characterized by many specimens of a large *Receptaculites*, is immediately subjacent to the Richmond. These stratigraphic conditions clearly indicate that in post-Kimmswick time the region was elevated above sea level, and the beds obliquely truncated before the deposition of the Richmond. The time hiatus represented by the unconformity in this region, as in Calhoun County, is doubtless the period during which the Utica and Lorraine formations were being deposited east of the Cincinnati arch.

In Monroe County, Illinois, conditions identical with those in Jefferson County, Missouri, are shown in the quarry of the St. L. I. M. & S. R. R. at Valmeyer. Still farther south, at Cape Girardeau, Missouri, the same section is repeated in the same manner, although the details have not been so carefully studied as in the more northern localities.

In the northern portion of the Mississippi Valley region, in eastern Iowa, northwestern Illinois, and Wisconsin, no stratigraphic break between the Galena limestone below, which is contemporaneous with the Kimmswick limestone, and the superjacent Maquoketa shales has been certainly established, but the faunal break is essentially identical with that in Calhoun County where the physical break is clearly shown, and one is forced to the conclusion that the physical unconformity is really present, although obscured.

Westward from the Mississippi River, across the great plains, the older rocks are completely buried beneath younger formations. In the Big Horn Mountains in Wyoming, however, as has recently been shown by Darton,[1] conditions are present which are comparable to

[1] "Geology of the Big-Horn Mountains," *U. S. Geological Survey*, P. R. No. 51, pp. 26–29; also *Bull. Geol. Soc. Am.*, Vol. XVII, p. 547.

those in the Mississippi Valley. In this western region the great mass of the Big Horn limestone corresponds essentially in age to the Kimmswick limestone, but at the summit of the formation, in discontinuous, pocket-like areas, as if deposited unconformably upon the eroded or weathered surface of the subjacent beds, are strata bearing a rich and typical Richmond fauna with *Rhynchotrema capax*.

With this unconformity clearly established in the Mississippi Valley and in the Big Horn Mountains, and with the faunal conditions so nearly alike in the two regions, we seem to be justified in considering the same unconformity as being present in all the intervening area. If this conclusion is well founded, there must have been in post-Trenton time a great expanse of dry land in the interior of the North American continent, reaching from the Cincinnati arch probably to the Rocky Mountain region, which in Richmond time was resubmerged.

Such a widespread emergence and resubmergence of the interior of the continent should constitute an important and clearly marked epoch in geologic history, perhaps of sufficient importance to rank as a major division in this history. As we now understand the facts, there seems to be no such conspicuous break between the recognized summit of the Ordovician and the base of the Silurian, as this preceding the Richmond. A thorough and systematic investigation of the entire Richmond and Maquoketa fauna, together with a careful comparison with the earliest Silurian faunas is highly desirable. It is especially desirable that the earliest faunas of the Medina sandstone of the east be better known, in order to determine whether there exists any relationship between them and the Richmond faunas of the Mississippi Valley. In a certain way the Richmond is perhaps analogous with the Helderbergian which was formerly considered as the youngest Silurian, but is now almost universally considered as the oldest Devonian. It is certainly within the limits of possibility that, with a more complete knowledge of the facts, the Richmond may be transferred in a similar way, and be considered as the oldest Silurian, rather than as the youngest Ordovician.

ON THE ORIGIN AND DEFINITION OF THE GEOLOGIC TERM "LARAMIE"[1]

A. C. VEATCH

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INTRODUCTION

Investigations of the United States Geological Survey during the summer of 1906, covering the larger part of the Laramie exposures on the Laramie Plains, examined by the King and Hayden surveys, have revealed many new and important facts bearing on the Laramie problem.

By detailed areal surveys it was found: (1) that the lignitiferous series, which in the Laramie Plains lies between the Montana below and the Fort Union above, and has a maximum thickness of about 12,500 feet, is divided about the middle by an unconformity; (2) that this unconformity is in the same stratigraphic plane and continuous with the unconformity which in the vicinity of Carbon and to the southeast separates all the Laramie beds studied by the Hayden and King parties from the underlying Cretaceous; (3) that the beds above the unconformity rest, often with great divergence of dip, on all the underlying beds down to and including the Dakota; (4) that the basal conglomerate, locally well developed at the horizon of the unconformity, while composed largely of materials derived from the underlying Cretaceous rocks, notably the Benton, contains pebbles and bowlders from the pre-Cambrian crystallines now exposed in

[1] Published by permission of Director of the U. S. Geological Survey.

the hearts of the surrounding ranges. This unconformity thus involves the total thickness of the Cretaceous portion of the beds below the unconformity, and probably the whole sedimentary series of this region, or over 20,000 feet of strata.

The Laramie Plains section in brief is as follows:

GENERALIZED SECTION OF THE ROCKS OF THE WESTERN PART OF THE LARAMIE PLAINS IN CARBON COUNTY, WYOMING

	North Park Tertiary	4,500+
	Unconformity	
	Fort Union	800–2,000
	"Upper Laramie"	6,000
	Unconformity	
	"Lower Laramie"	6,500
Montana	Lewis } "Fox Hills" of the early surveys	3,000
Montana	Mesa Verde } "Fox Hills" of the early surveys	3,200
Montana	"Pierre shale"[1]	3,500
Colorado	Niobrara	800
Colorado	Benton	1,500
	Dakota	150
	Morrison	200
	Marine Jurassic	75
	Red beds	1,650
	Carboniferous sandstone and limestone with basal conglomeratic quartzite	1,800
	Pre-Cambrian crystallines	

It may be said that in the areas examined by the Hayden and King parties, all of which were immediately along and south of the Union Pacific Railroad, the lower division is usually absent, the upper resting generally on one or another of the members of the Montana, but at one point extending over on to the Dakota. The large development of the division beneath the unconformity and above the Montana, corresponding to the "Lower Laramie" of literature, lies entirely north of the area they studied, and its existence was not known until the work of the past season.

[1] It is the belief of Dr. T. W. Stanton that the Mesa Verde and part of the Lewis belong to the Pierre, as that formation is developed east of the Rocky Mountains. A local name will therefore be applied to this lowest division of the Montana in this section.

PRESENT USAGE OF THE TERM "LARAMIE"

The three principal usages of the term "Laramie" today are shown in the recent textbook of geology by Chamberlin and Salisbury. Here "Laramie series" is applied to all the beds between the Montana and Fort Union. Upper Laramie and Lower Laramie or "Laramie proper" are applied respectively to the beds above and below the great unconformity, first shown by Cross to exist in the Denver region, then found by Weed in western Montana, in 1905 found in southern Uinta County, Wyoming, by the writer, and traced northward by Dr. Schultz in 1906 to a point just south of Yellowstone National Park, and again found in 1906, most strikingly developed, in Carbon County, Wyoming, in the western part of the Laramie Plains. The Lower Laramie has also been called "true Laramie," and sometimes simply Laramie. The complexness of the situation is excellently illustrated by the use of "Laramie" by Stanton and Knowlton in seven different combinations on a single page of their report, namely "Laramie series," "true Laramie," "so-called Laramie," "original Laramie," "typical Laramie," "the Laramie," "supposed true Laramie."[1]

Because of the frequent and necessary reference to the upper and lower divisions in the present discussion, the names "Upper Laramie" and "Lower Laramie" will be applied in this discussion in the sense used by Chamberlin and Salisbury, and in other geologic literature.

KING'S STATEMENT

A critical historical consideration of the origin of the word "Laramie," which may be expected to lead to some scientifically defensible conclusion regarding what the term can and cannot be properly used for, may very naturally begin with King's explanation in his *Systematic Geology of the Exploration of the Fortieth Parallel.* King here makes three important references to the subject, which because of their intimate bearing on this discussion are quoted at length:

> Conformably overlying the Fox Hill group of Hayden is a considerable series of rocks over which a conflict of opinion now exists. These rocks Dr. Hayden has successively considered as Tertiary and as transitional between the Cretaceous

[1] "Stratigraphy and Paleontology of the Laramie and Later Formations in Wyoming," *Bulletin of the Geological Society of America*, Vol. VIII (1897), p. 128.

and the Tertiary. They conformably overlie the Fox Hill of Meek and Hayden, and are developed throughout a large part of Wyoming, as well as upon the great plains east of the Rocky Mountains south of the forty-first parallel. That there might be no misunderstanding as to the stratigraphical position and nature of the rocks themselves, Dr. Hayden and I mutually agreed to know them hereafter as the Laramie group, and to leave their age for the present as debatable ground, each referring them to the horizon which the evidence seemed to him to warrant.[1] . . . .

The great sandstone series of the Fox Hill is conformably overlain by a continuation of the sandstones, which attain a thickness of from 1,500 to 5,000 feet, varied very greatly in lithological character over different areas, but in general characterized by the frequent occurrence of workable beds of lignite and innumerable seams of carbonaceous clay. The fossil forms which are found in this series have led to a disagreement, which has now become historic, as to the age of the beds. They were at first, by Meek and Hayden, held to be distinctly Tertiary. That opinion has since been so modified as to lead those gentlemen to designate them as beds of transition. On the other hand, Dr. Le Conte, Professor Newberry, Professor Stevenson, and Major Powell have all committed themselves to the view advanced by me in Volume III of this series in 1870, that the whole of the conformable series is Cretaceous. During the slow gathering of the evidence which shall finally turn the scale, I proposed to Dr. Hayden that we adopt a common name for the group, and that each should refer it to whatever age his data directed. Accordingly, as mentioned in the opening of this chapter, it was amicably agreed between us that this series should receive the group name of Laramie, and that it should be held to include that series of beds which conformably overlies the Fox Hill.[2] . . . .

Here, with those who follow Hayden, the Cretaceous series comes to an end. Conformably over this lies the group which Hayden and I have agreed to call the Laramie, which is his Lignitic group, and is considered by him as a transition member between Cretaceous and Tertiary. There is no difference between us as to the conformity of the Laramie group with the underlying Fox Hill. It is simply a question of determination of age upon which we differ.[3]

It is evident from the above: (1) that Laramie was adopted as a name for the beds which Hayden called Lignitic in Wyoming and Colorado,[4] and (2) that the beds so included were believed by both Hayden and King conformably to overlie the Fox Hills sandstone. Considered with other available data, it is unquestionably true that

[1] *Report of the Geological Exploration of the Fortieth Parallel*, Vol. I (1878), p. 298.

[2] *Ibid.*, p. 331. [3] *Ibid.*, p. 348.

[4] This is further shown by the following phrases on p. 333 of King's report: "The Laramie or Lignitic period," "Hayden's Lignitic (now the Laramie) series."

both King and Hayden intended that the term should apply to the beds which occur between the Fox Hills and the Wasatch.

The consideration that the name was adopted as a substitute for Hayden's Lignitic suggests that the proper way to approach this somewhat involved subject is through the writings of Hayden. A number of collateral facts tend to strengthen the view that in a critical discussion of the origin and definition of Laramie the writings of Hayden are of prime importance. In the first place, King did not personally desire to investigate the region from Fort Bridger eastward, and only undertook it when the chief of engineers so directed. On January 23, 1871, he wrote the chief of engineers as follows:

> The parties under the charge of Dr. F. V. Hayden, geologist of the Interior Department, and that led by Professor O. C. Marsh, of Yale College, have devoted the past summer to the geological explorations of those portions of Wyoming and Colorado which I had intended to cover next summer. . . . . I am convinced that what I could do would add but little to results they have obtained. We should without doubt fill up minor gaps in the structural relations of the plains, but on the whole it seems to me that there is not sufficient inducement to warrant our devoting our time and funds to a field from which the cream has already been taken.

In a letter to the chief of engineers, dated February 9, 1871, he gave the exact limit of his previous work as follows:

> In answer to the communication of Colonel J. B. Wheeler which I have just received, concerning the extent of the Green River included within my explorations, I have the honor to say that no part of that section is embraced in the work already done. Our eastern limit is 30 miles west of the river. If my present plans are carried out, I had not intended to continue that way.

On the direction of the chief of engineers the work was continued eastward, but King's personal efforts were almost wholly devoted to the territory to the west of Green River. In 1871 S. F. Emmons passed rapidly up Bitter Creek Valley, examining the country as far east as Washakie. In 1872 he spent ten days, June 20 to 30, examining the immense territory west of the North Platte River, south of the Seminoe Mountains, and north of the Elk Mountains.[1] The outcrops in the Laramie Plains were examined by Arnold Hague in the fall of 1872. When King therefore agreed with Hayden on a

[1] King's manuscript letters to the chief of engineers, dated July 3, 1872, and February 17, 1873.

name which should be a substitute for and equivalent of Hayden's Lignitic as used in Colorado and Wyoming, he necessarily relied upon Hayden's work on the Laramie Plains with the corroboration furnished by the work of Hague and such hasty examinations as he may have made personally when visiting Hague's party. It is therefore essential to take up first the work of Hayden, and to trace the natural growth and development of his knowledge which made "Laramie" an entirely natural and desirable term to Hayden.

BOUNDARIES OF THE LARAMIE PLAINS

Before following up the suggested clue afforded by the writings of Hayden, it may be well to outline the boundaries of the Laramie Plains as they were understood at the time of the adoption of the word "Laramie." On all the army maps[1] of this region the Laramie Plains are shown as extending from the Front Range westward to the region of the North Platte River. In 1871 Professor Cyrus Thomas, of the Hayden Survey, gave the following definition of the Laramie Plains:[2]

> This section is bounded on the east and northeast by the Black Hills,[3] on the west by the West Rattlesnake Hills,[4] and on the southwest by Medicine Bow Mountains. It is somewhat quadrangular in shape, its average length from southeast to northwest being about 90 miles, and average width from northeast to southwest about 75 miles, containing (exclusive of the surrounding mountains) a surface area of about 6,750 square miles, or nearly 4,500,000 acres. It is drained chiefly by the Medicine Bow and Laramie Rivers and their tributaries, both affluents of the North Platte, which also traverses the extreme western border. The Laramie, rising in the mountains at the southwest angle, flows along the eastern border to the northeast angle of the section, where it breaks through the Black Hills and joins the North Platte in the plains beyond. The Medicine Bow, receiving affluents from each side, but principally from the south, flows through the western part of the section and joins the North Platte on the western border; which latter stream makes its exit at the northwest angle. . . . .
>
> The southeast part, to which the name "Laramie Plains" is sometimes limited, is decidedly the best portion of the section, and contains much the largest propor-

[1] These were the general maps in common use by the Hayden and King parties.

[2] *Fourth Annual Preliminary Report*, U. S. Geological Survey of Wyoming (being a *Second Annual Report of Progress*), (1871), pp. 220, 221.

[3] Now called the Laramie Hills or Front Range.

[4] Now called the "Haystacks" and situated just west of the North Platte River in Carbon County, Wyo.

tion of arable land. Counting from the head of the Laramie Valley to Rock Creek, it is about 70 miles long, with an average width of about 25 miles, giving an area of 1,750 square miles.

Thus there appear to have been two usages for the term "Laramie Plains"—one in common use on the army maps and, to a greater or less extent, among the people, as is shown in official reports of the surveyor general of Wyoming;[1] and a second restricted to the portion east of Rock River (sometimes also given as Medicine Bow River). The term was not extended to the plains west of the natural western limit afforded by the West Rattlesnake Hills or Haystacks. Hayden used the term in both senses. In his report for 1868 he says: "In the Laramie Plains, along the line of the Union Pacific Railroad, extensive beds of coal have been opened, and the coal is used for generating steam and for fuel on the cars."[2] This is clearly a reference to the mines at Carbon.

In 1869 he said, in speaking of a trip from Fort Sanders to Fort Fred Steele: "Our course was along the Overland Stage Road just at the base of the mountains, on the south side of the Laramie Plains, from 5 to 20 miles south of the Union Pacific Railroad line."[3]

In his report for 1870 Hayden used "Laramie Plains" both in the limited and in the broader sense. Thus the statement that the "entire surface of the plain east of the Medicine Bow forms one vast pasture ground" implies clearly that there are two portions of the plain, one east and one west of the Medicine Bow River.[4]

The statement that the Laramie Plains "is usually understood to extend westward almost to the Medicine Bow River"[5] is clearly the

[1] *Annual Report of the Commissioner of the General Land Office* for 1871, 1872, p. 271; see also *Fourth Annual Report*, U.S. Geological Survey of Wyoming (1871), p. 251.

[2] *Proceedings of the American Philosophical Society*, Vol. X (1868), p. 467; [*Second Annual Report*, U. S. Geological Survey of the Territories, 1868] *Report of the Commissioner of the General Land Office* for 1868, 1868, p. 233; *First*, *Second*, and *Third Annual Reports*, U. S. Geological Survey of the Territories for 1867, 1868, and 1869, p. 80. This statement should be compared with the statement on p. 89 of the last report (p. 242 of the original Land Office report), where it is stated that the Laramie Plains are 60 miles from east to west. This width, when compared with Thomas' statement, places the western edge of the Laramie Plains near the North Platte River.

[3] *Proceedings of the American Philosophical Society*, Vol. XI (1869), p. 34.

[4] *Fourth Annual Report*, U. S. Geological Survey of Wyoming and Contiguous Territories (being a *Second Annual Report of Progress*), (1871), p. 79.

[5] *Ibid.*, p. 121.

restricted usage, unless it is held that the expression "North Platte River" was really intended instead of Medicine Bow River—a view which is sustained by the width of 50 miles from east to west which is given for the plain, and by other expressions given in the context; while in the statement that the North Platte River cuts its "way through immense canyons between the North Park and the Laramie Plains," and again, "the Medicine Bow and the two Laramies . . . . take their rise in the elevated snow-capped mountains on the south side of the Laramie Plains,"[1] the term is clearly used in its broader sense. In all of the geological references the term is used in its broader sense.

Hague, in speaking of the western limit of the Laramie Plains, says in 1878:

> To the northwest, however, the Plains are not entirely rimmed in, the open country stretching for a long distance without marked geographical boundary. For most purposes, however, it will be well to regard the western boundary of the Plain as limited by the Como Ridge just north of the Medicine Bow Range. . . . . As thus defined, the Laramie Plains measure at least 80 miles in length by about 30 miles in breadth.[2]

This is clearly the restricted usage, but it recognizes a broader usage. It is in this broader sense that the phrase "Laramie Plains" is used by the present writer.

HAYDEN'S INVESTIGATIONS

Hayden studied the exposures in the Laramie Plains in 1867, 1868, 1870, and 1875. In the fall of 1867, after the completion of the field-work on the geology of Nebraska Territory, he passed over the Front Range into the Laramie Plains and proceeded along the Overland Stage Road as far west as the now famous Rock Creek locality.[3] He then proceeded by way of the Overland Stage Road to South Bowlder Creek, a short distance north of Denver, thence northward

[1] *Ibid.*

[2] *Geological Exploration of the Fortieth Parallel*, Vol. II (1877 [1878]), p. 73.

[3] *American Journal of Science*, Second Series, Vol. XLV (1868), pp. 101, 102 (letter to J. D. Dana, dated Cheyenne City, Dakota Territory, October 31, 1867); *ibid.*, pp. 199, 200, 204, 205; *Final Report*, U. S. Geological Survey of Nebraska (1872), pp. 46, 54, 55. Hayden states that the last report was printed without revision in exactly the same form, except for certain omissions, as it was transmitted to the commissioner of the General Land Office on March 1, 1868.

to Cheyenne along the east base of the mountains. In this investigation he recognized in the Laramie Plains Cretaceous beds up to and including the Fox Hills,[1] and found that "at Rock Creek, about 40 miles west of the big Laramie River, the lignite beds overlap[2] the Cretaceous."[3] He collected from these lignite beds "in the Laramie Plains . . . . two species of plants, a *Populus* and a *Platanus*, specifically identical with those found on the upper Missouri."[4] This collection of plants was studied by Lesquereux[5] and listed as from "Rock Creek, Laramie Plains." As knowledge of the flora progressed, Lesquereux referred this collection to the same horizon as the Carbon plant-beds,[6] and in the light of present knowledge there can be no reasonable doubt that they came from the same formation. After his field-work of 1867, Hayden announced the doctrine, entirely natural from his knowledge of and experience with the coal-bearing beds in the Dakotas, eastern Montana, and northeastern Wyoming, that all the coal-bearing beds of the Rocky Mountain region are younger than the Fox Hills. He thus included certain Upper Montana coal-bearing beds which in the region of Rock Creek directly underlie the Upper Laramie strata containing the plants referred to above.

In 1868 Hayden, continuing the "Survey of the Territories," extended his investigations of the Laramie Plains. He proceeded from Fort Sanders along the Overland Stage Road as far as Pass Creek, and then turned north to Fort Steele. Returning to Fort Sanders, he proceeded to examine the geology along the line of the Union Pacific Railroad from Fort Sanders westward.[7] In his account

[1] *Final Report*, Geological Survey of Nebraska (1872), p. 55.

[2] From the usage of the word "overlap" through Hayden's writings, it is believed that he used the word as a synonym of "overlie," and not in its present technical geologic sense.

[3] *American Journal of Science*, Second Series, Vol. XLV (1868), p. 205.

[4] *Ibid.*, p. 204; see also p. 101; and *Final Report*, Geological Survey of Nebraska (1872), p. 55.

[5] *American Journal of Science*, Second Series, Vol. XLV (1868), p. 205; [*Third Annual*] *Preliminary Field Report*, U. S. Geological Survey of Colorado and New Mexico (1869), pp. 95, 96.

[6] *Fifth Annual Report*, U. S. Geological Survey of Montana for 1871, 1872, p. 306.

[7] [*Second Annual Report*, U. S. Geological Survey of the Territories, embracing Wyoming] *Report of the Commissioner of the General Land Office* for 1868, 1868, pp.

of this trip he describes the exposures along the Overland Stage Road, and among the beds which he studied, and then referred to the Lignitic, there are none which are now known to belong to the Lower Laramie, or the "true Laramie" of recent geologic literature. He states that he found "great quantities of deciduous leaves" (which "indicate the Tertiary age of the rocks, and also show that they jut far up close to the foothills of the mountains") in strata which are now known to be Upper Laramie and which in that immediate region rest unconformably on all beds down to the Dakota. The preponderance of evidence indicates that it was from this locality on the overland trail just west of Rock Creek that he obtained the leaves identified by Lesquereux as from "Rock Creek, Laramie Plains," which are clearly Upper Laramie. He also examined the strata and collected leaves from the Upper Laramie beds at a point just north of Medicine Bow stage station (now Elk Mountain post-office). The Upper Laramie beds at this point rest on the Lewis shales, which because of the coal-bearing character of the underlying Mesa Verde beds Hayden at this time included in his Tertiary.

Along the railroad he found only Cretaceous outcrops until he reached a point 5 miles east of Como, where he reports a sandstone "with fragments of stems and leaves," which he at first thought was probably lower Tertiary.[1] Continuing, he says:

> From a point about 10 miles west[2] of Como to St. Mary's Station . . . . the Tertiary formations occupy the country with the peculiar sands and sandstone and clays, and numerous coal-beds. The most marked development of the coal-beds is at Carbon Station, about 80 miles west of Laramie Station. . . . . In the beds above and below the coal are thousands of impressions of deciduous leaves, as *Populus, Platanus, Tilia,* etc. Some of the layers of rocks 2 to 4 inches in thick-

242–49; reprinted in *First, Second,* and *Third Annual Reports,* U. S. Geological Survey of the Territories (1873), pp. 89–96; *Proceedings of the American Philosophical Society,* Vol. XI (1869), pp. 28–38, 54, 55.

[1] This sandstone is low in the Cretaceous, and on second thought Hayden referred it to the Cretaceous (*Proceedings of the American Philosophical Society,* Vol. XI [1869], p. 370 . He re-examined the locality in 1870 and again referred it to the Cretaceous.

[2] In the original this reads "east," but when compared with the statement that the Cretaceous rocks continue to a point about 5 miles east of Como, and when considered in connection with the general lay of the country it undoubtedly should be "west." It is changed to "west" in the reports for 1870 ([*Fourth Annual*] *Preliminary Report,* U. S. Geological Survey of Wyoming [1871], p. 164).

ness are wholly composed of these leaves in a good state of preservation, and so perfect are they that they could not have been transported any great distance.[1]

The extreme western portion of the area described by Hayden in the above as occupied by the Tertiary—that is, the region in the immediate vicinity of St. Mary's station—is underlain by Lower Laramie strata, but along the railroad the beds are almost entirely covered by Quaternary débris. The beds actually studied by Hayden in this area, and upon which he based his opinion, are certainly wholly Upper Laramie.

In summarizing his results in a letter written from the field to the commissioner of the General Land Office, Hayden shows that he had already begun to suspect that his decision that all coal-bearing beds in this region are Tertiary is not well founded. In the same letter he announces his unqualified belief that the Tertiary beds—that is, those yielding the plants at Carbon, Medicine Bow stage station, and Rock Creek—are unquestionably conformable with the Cretaceous. He says:

We have taken the position also that the coal-bearing beds of the Laramie Plains are of Tertiary age, although some marine fossils are found in strata connected with the coal. There may be some thin seams of impure coal in the upper Cretaceous beds. . . . . I can find no want of conformity between the Tertiary and Cretaceous beds, and indeed so gradually and imperceptibly do the Cretaceous beds pass up into the Tertiary that I have not been able to determine the line of separation.[2]

In a review of the same subject before the American Philosophical Society on February 19, 1869, Hayden clearly shows that he regards the Carbon locality as not only the most important locality in the Laramie Plains, but as the connecting link between the great Lignitic group of the Missouri River (which he then, because of the flora, regarded as Miocene) and the coal-bearing deposits of Wyoming. He says, in summarizing his geological observations at this time:

The Cretaceous formations occupy the country for 60 miles from Laramie City to Lake Como. Genuine Jurassic beds . . . . are here exposed for a short

[1] [*Second Annual Report*, U. S. Geological Survey of the Territories] *Annual Report*, Commissioner of the General Land Office for 1868, 1868, p. 249; *Proceedings of the American Philosophical Society*, Vol. XI (1869), p. 37.

[2] *Annual Report*, Commissioner of the General Land Office, for 1868, 1868, p. 253; *First, Second*, and *Third Annual Reports*, U. S. Geological Survey of the Territories (1873), p. 100.

distance. Cretaceous beds, mostly No. 2, appear again west of Como. Miocene coal-beds overlay the Cretaceous just before reaching Carbon Station, 80 miles west of Laramie. At Carbon, where they are exposed to view, impressions of fossil leaves occur in the greatest abundance. The species are few, and nearly all of them identical with those described by Dr. Newberry, from the Miocene Tertiary beds of the Upper Missouri. Some strata consist almost entirely of leaves, in a fair state of preservation, as if they had not been subjected to a great deal of drifting prior to deposition. Indeed the trees themselves must have grown near the spot, to shed their leaves in such great abundance, just as we find leaves accumulated now in muddy bottoms. Dr. Newberry has identified from this locality, *Populus cuneata*, *Populus Nebrascensis*, *Platanus haydeni*, and an undescribed species of *Cornus*. The Wyoming Coal Company's shaft, sunk at this station to reach the coal, has descended nearly 60 feet through a considerable thickness of bluish-black arenaceous clay, in rather thick layers, upon the surface of which are great quantities of *Populus* and *Platanus*. Very nearly the same species are described [found] throughout a great thickness of these Tertiary beds, and the evidence seems to be pretty clear that the vegetation was nearly uniform throughout the period of the deposition of the coal strata.[1]

Although Hayden did not work in this region in 1869, he referred to the area in his "Review of the Leading Groups" in his report for this year. In this account he definitely refers the beds on the Laramie Plains (and for the first time) to "the great lignite group,"[2] and indicates that in the region west of the Laramie Plains he considers it limited above by the Washakie group.

In 1870 Hayden, starting at Cheyenne, traveled northward to the Platte River, and thence westward along the old emigrant road through Smith Pass to Fort Bridger. Returning, he followed the Overland Stage Road up Bitter Creek Valley through Bridger Pass to Laramie City, and then re-examined the geology along the line of the railroad west of that point. In the report for this year he still refers some of the Montana and older Cretaceous sandstones containing coal-beds to the Tertiary, but there is evidence of a growing suspicion that they may be Cretaceous.[3] He even goes to far as to say: "The evidence seems to point to the Cretaceous age of the coal group

[1] *Proceedings of the American Philosophical Society*, Vol. XI (1869), pp. 54–55.

[2] "Along the line of the Union Pacific Railroad we find in the Laramie Plains a most extensive exhibition of the great lignite group."—[*Third Annual*] *Preliminary Field Report*, U. S. Geological Survey of Colorado and New Mexico (1869), p. 90.

[3] [*Fourth Annual*] *Preliminary Report*, U. S. Geological Survey of Wyoming for 1870, 1871, p. 165.

in Weber Valley."[1] He strongly emphasizes in this report the importance of the Laramie Plains localities, particularly Carbon, in the determination of the question of the age of these beds. He certainly singles out Carbon as the one locality at which the age can be fixed, regarding the flora as there developed as the important connecting link between the coal-bearing beds of Wyoming and those of the Missouri River region. He says:

> The most important coal-mines are located at Carbon. No shells have ever been observed in connection with the coals, but thousands of impressions of deciduous leaves are found. It is important to fix the age of the coal-beds in any one locality. So far as we can determine, the coal-beds of the Laramie Plains are of Eocene age, although the plants are more closely allied to those of the Miocene period in the Old World.[2]
>
> So far as the Evanston coal-mines are concerned . . . . I discovered a magnificent series of fossil leaves, among which Dr. Newberry informed me he had detected species identical with those occurring in connection with the coal-beds of the Laramie Plains and on the upper Missouri.[3]

In 1872 Hayden directed Lesquereux to make explorations in Colorado and Wyoming with a special "view to positively ascertaining the age of the Lignitic formations, either from data obtainable in collecting or examining fossil vegetable remains or from any geological observations which I [he] should be able to make."[4] In this examination he visited Rock Creek and Carbon. At Rock Creek he failed to find the locality from which Hayden obtained his leaves, finding only outcrops yielding characteristic upper Cretaceous marine forms.[5] He thus anticipated, as Hayden had before, and perhaps to a more complete degree, anticipated by the finding of Fox Hills sandstones on Rock Creek,[6] the conclusions reached many years later by Drs. Stanton and Knowlton[7] at this locality. At Carbon he included with the Lignitic, because of the presence of the fucoid *Helemynites*, which he then supposed to be characteristic of the Lignitic,

[1] U. S. Geological Survey Report, *loc. cit*, p. 167.

[2] *Ibid.*, p. 164. [3] *Ibid.*, p. 167.

[4] *Sixth Annual Report*, U. S. Geological Survey of the Territories for 1872, 1873, p. 317.

[5] *Ibid.*, p. 330.

[6] *Bulletin of the Geological Society of America*, Vol. VIII (1896), pp. 137–43.

[7] [*Fourth Annual*] *Preliminary Report*, U. S. Geological Survey of Wyoming (1871), p. 79.

but which is more abundant in the upper Montana,[1] certain Cretaceous coal-bearing sandstones which are now known to be Mesa Verde. With this exception, Lesquereux studied only beds of Upper Laramie age, making large collections from the immediate vicinity of the mines. He studied and recognized the sea-beach character of the conglomeratic sandstones just west of Carbon, which are now recognized as the base of the Upper Laramie. This conglomeratic sandstone contains pebbles now known to have been derived from the underlying Cretaceous and older rocks, and indicates an immense unconformity. His report, in the light of present knowledge, is extremely suggestive. Thus he refers the beds at Carbon to the "upper Lignitic" and suggests the equivalence of the conglomeratic sandstone just mentioned with "that of the upper member of the Lignitic of Colorado" (possibly meaning beds since reported as the Arapahoe).

Two reports by Hayden, clearly written before the final adoption of the word "Laramie," complete the history of the development of his knowledge and belief in this critical period. In a "Brief History of the Lignitic Group"[2] Hayden states that "the Lignitic group of the Northwest [is] believed to be continuous southward with the Colorado and Laramie beds." In this report Hayden finally acknowledges the presence of coal in beds of true Cretaceous age, saying:

> One fruitful source of difference of opinion has been in the misunderstanding in regard to the different horizons of the coal strata of the West. That there are important coal-beds in rocks of well-defined Cretaceous age cannot be disputed, and I have long since yielded that point. What we wish to show more clearly is that there exists in the West a distinct series of strata which we have called the Lignitic group, and that it is entirely separate paleontologically and geologically from a great group of strata in the lower Cretaceous,[3] and perhaps extending down into the Jurassic, which contain a great number of thick and valuable beds of coal. It is not necessary to discuss the question whether the term Lignitic should be applied to either or both groups. I have used the term Lignitic for the upper

[1] Hayden recognized this in 1875 (*Bulletin*, U. S. Geological and Geographical Survey of the Territories, Vol. I [1876], p. 404), and it has since been abundantly proven.

[2] *Eighth Annual Report*, U. S. Geological Survey of the Territories for 1874, 1876, pp. 19–27.

[3] The phrase "lower Cretaceous" is not here used in the present technical sense (Lower Cretaceous or Comanche beds were unknown to Hayden) but rather in the sense of underlying.

group without reference to the quality of the fuel simply to distinguish it from the other great group of older age, the age of which is not questioned. . . . . It is well known that I have held with some tenacity the opininon that the coal formations of the West are of Tertiary age; and I still regard the Lignitic group proper as transitional or lower Eocene.

The name "Laramie beds" is used in the first of the above quotations in a simple geographic sense, but it clearly indicates what to Hayden was a most natural term. In the Hayden report for 1873, published in 1874, Marvine, in discussing the exposures in the vicinity of Denver and Golden, Colo., used the geographic name "Colorado Lignitic group,"[1] with the suggestion "that the extended explorations of Hayden and others would seem to prove almost conclusively that the Colorado Lignitic group is the direct southern stratigraphical equivalent of the Fort Union group of the upper Missouri." But he adds the precautionary statement: "When all the facts are known, they may develop some new ideas as to geological transitions." The Colorado beds in the above clause from Hayden's *History of the Lignitic Group* are clearly the same as the "Colorado Lignitic group" of Marvine, and there was thus at this time two natural names for the Lignitic group as developed in Wyoming and Colorado—the Colorado group and the Laramie group. When Hayden and King agreed to use the term "Colorado group" as an appropriate name for the combined Fort Benton, Niobrara, and Pierre,[2] the term "Laramie group" was left as the natural and appropriate designation.

In "Notes on the Lignitic Group of Eastern Colorado and Portions of Wyoming," which appears to have been the last paper written by Hayden on this subject before the adoption of Laramie, he states that

throughout the Lignitic proper, that is the portion occurring above the Fox Hills group, I have never found any true nonconformity. That there may be in some places an interrupted sequence in the beds is quite possible. . . . . That there have been many oscillations of the surface, that it has been alternately above and below water many times, may be inferred from the numerous coal-beds. In the aggregate, there could hardly have been any marked interruption in the sequence of the deposition, even up to the summits of the highest Tertiary, though between

[1] *Seventh Annual Report*, U. S. Geological and Geographical Survey of the Territories for 1873, 1874, p. 107.

[2] *Report of the Geological Exploration of the Fortieth Parallel*, Vol. I (1878), p. 298.

the Lignitic group and the more modern Tertiaries, as the Washakie, Green River, and other fresh-water groups, there is at this time a true nonconformity. . . . . If we could look beneath the horizontal strata of the Washakie group between Separation and Bitter Creek, or under the Bridger and Green River groups along the immediate line of the railroad, we might find localities where the sequence of the beds is not interrupted, and yet, in the immediate vicinity of the mountain-ranges, as the Uintah, for example, the modern fresh-water Tertiaries rest unconformably on the older rocks.[1]

This clearly shows that in this region Hayden regarded the Lignitic as limited below by the Fox Hills and above by the Washakie (Wasatch or Vermilion Creek) group. That he had already begun to suspect the existence of a break at the base of the Laramie is suggested by the following statement:

It is evident that in many localities, and possibly throughout eastern Colorado, a considerable portion of the Upper Fox Hills group is wanting. Sometimes the Lignitic group is deposited on No. 4 or No. 3 Cretaceous. Therefore there is undoubtedly a conformable interrupted sequence; in other words, while the Lignitic group appears to conform to the underlying beds, there really are wanting hundreds, and perhaps thousands, of feet of strata which at some other locality in the West may exist.[2]

HAGUE'S STUDIES

Another line of evidence is perhaps needed to give the complete historical background necessary to reach a correct conclusion in this question of the origin and definition of the term "Laramie." There are a number of reasons for believing that not only was the term "Laramie," as has been shown, the most natural name for Hayden to suggest when asked by King for an appropriate term,[3] but it was also the name which was independently suggested to King by Hague.[4]

[1] *Bulletin*, U. S. Geological and Geographical Survey of the Territories, Vol. I, No. 5 (January 8, 1876), p. 410.

[2] *Ibid.*, p. 404.

[3] Dr. A. C. Peale has informed me that he has in his possession a letter from King to Hayden, bearing a date later than November 15, 1875, requesting that he, Hayden, propose a name for the Lignitic.

[4] Verbal statement by Mr. Hague to the author, corroborated by the use of the term "Laramie" on a map issued by the King Survey, November 15, 1875. See *American Journal of Science, Third Series*, Vol. XI (1876), p. 161; *Bulletin*, U. S. Geological Survey of the Territories, Vol. III (1877), p. 182; *Bulletin No. 82*, U. S. Geological Survey (1891), p. 147.

Mr. Hague studied the region of the Laramie Plains in the fall of 1872. At the Rock Creek locality he reports and maps only Fox Hills strata,[1] although he states he did not see the coal openings reported by Hayden, near one of which typical Upper Laramie plants have since been found,[2] thus confirming the early observations of Hayden. Carbon was therefore the only locality on the Laramie Plains where Hague recognized Laramie strata. The strata at this point which he refers to the Laramie are clearly Upper Laramie.

In opening the discussion of the Carbon locality, Hague says:

> Geologically the place has also received considerable attention in examining the question of the age of the Wyoming coals. There would appear to be but little doubt that the beds belong to the Laramie division of the Cretaceous sandstone.

It would certainly have greatly simplified one point in the consideration of this greatly involved subject if Hague had said here, as he has since said in conversation, that the beds are called Laramie because of their exposure at this point on the Laramie Plains. It is unquestionably the only point on the Laramie Plains where the Laramie beds were recognized and critically studied by the King Survey, and King was too keenly alive to the absolute importance of a geographic origin for geologic names (the names being derived from type localities at which the beds were well exposed and could be unquestionably defined) to have permitted the adoption of, or even seriously considered, a term not definitely fixed in this way. His feeling in the matter is clearly shown by the fact that he refused to use the prior name "Wasatch" solely because at what he considered the type locality of Hayden, the Wasatch Mountains, the beds were not fully and typically exposed. He considered this sufficient reason to reject this name and to apply a new name, "Vermilion Creek group," taken from the locality where the beds were well exposed and could be fully defined.[3] In the light of these facts, it is clear that the

[1] *Report of the Geological Exploration of the Fortieth Parallel*, Vol. II [1877 (1878)], pp. 86–87.

[2] *Bulletin of the Geological Society of America*, Vol. VIII (1896), pp. 141, 142. The field-work of 1906 practically connected this locality with that at Carbon and completely confirmed the provisional reference by Dr. Knowlton.

[3] *Report of the Geological Exploration of the Fortieth Parallel*, Vol. I (1878), p. 354. King's belief that the name "Wasatch" was taken from the Wasatch Mountains is shown by a careful consideration of Hayden's writings to have been unfounded. The type

rhetorical doubt expressed in the above sentence from Hague's report relates solely to the point whether or not these beds were Cretaceous. No one has questioned or could question that they were Laramie, since they were the exposures which justified the use of the name. The question, as clearly shown by the preceding section and ensuing discussion, was solely the one of geologic age. Lesquereux, from large collections of plants at this point, had asserted that the beds were undoubtedly Miocene. Starting with this rhetorical question, Hague proceeds to "determine the true horizon of these beds," namely that they are Cretaceous, by "tracing out their relations with the great sandstone formation [Fox Hills] which forms all the higher ridges of the region," and by comparing "the strata with other similar localities." He then states that the "beds at Carbon occupy a broad, irregular-shaped basin, the rocks on the west, south, and east all dipping in toward the center, surrounding it completely on three sides." He reports that on the west the beds of Simpson Ridge may be traced "passing conformably under the level coal-bearing strata of the valley;" that on the east the same coal-bearing sandstones are underlain by beds preserving the same dip, and to the south the beds "appear to be perfectly conformable with the basin strata." In other words, in his opinion the conformability of these Laramie beds with the underlying strata at this point is completely demonstrated.[1]

locality, as shown by the description of Hayden, extends from Carter, Wyo., to the Narrows, on Weber River, 7 miles below Echo City, Utah. The name is derived from Wasatch Station on the Union Pacific Railroad in Summit County, Utah, situated about midway between Carter and The Narrows. In this section the beds are very fully and completely exposed. See in this connection *Professional Paper No. 56*, U. S. Geological Survey (1907), pp. 87, 88.

[1] Hague's conclusion is clearly based wholly on the exposures (1) on the east flank of Simpson Ridge immediately southwest of Carbon, and (2) those along the railroad just east of town. The basal sandstones of the Upper Laramie outcrop along the east flank of Simpson Ridge with so nearly the same strike as the "Fox Hills sandstones" of the ridge (which are really Mesa Verde and several thousand feet below the top of the Montana) that from the exposures at this point one would certainly not suspect an unconformity except from a very critical study of the source of some of the contained pebbles. Immediately north and south of these exposures there is, however, a very marked angular unconformity between the Upper Laramie and the underlying Cretaceous strata. At the point where Hague reported conformity the upper 2,000 feet of the Lewis and all of the Lower Laramie is wanting. A few miles to the south the same Upper Laramie beds rest on highly inclined rocks of Cretaceous age, down to and including the Dakota. East of Carbon, Hague fixed the base of the Laramie at

Taking up then the consideration of Lesquereux's conclusions, he decides that the age of the deposits

> rests either on the fossil plants which they contain or upon their stratigraphic position, and where such testimony disagrees it would seem that the latter must necessarily receive the greater weight. . . . . Professor Lesquereux, notwithstanding he feels so positive as to the Miocene age of the Carbon beds, does not hesitate to place them below the Green River series, giving them a position in relation to the latter horizon which few geologists will be disposed to dispute, and which the geological maps and sections accompanying this report conclusively prove. In the second chapter of this volume it will be shown that the Green River beds are undoubtedly of Eocene age, that they are . . . . underlaid by a heavy thickness of the Vermilion Creek series, also Eocene, and that the latter overlies unconformably beds occupying the same horizon as the Carbon formation, which we regard as of upper Cretaceous age.

CROSS'S REDEFINITION

Hayden and King clearly adopted the word "Laramie" for the beds between the marine Montana Cretaceous and Wasatch or Vermilion Creek Eocene. The next important advance in the knowledge of this subject resulted from the work of Cross and Eldridge in the Denver region. They found here that the Laramie as mapped by the Hayden Survey was broken by an immense unconformity, succeeded by a second one of minor importance.

Cross was thus confronted with the difficulty of determining whether the beds above the unconformity, or those below the unconformity, should most appropriately be called Laramie. After carefully considering the writings of King, and finding his statement that the Laramie included "that series of beds which conformably overlie the Fox Hills," Cross quite naturally decided that the term "Laramie" should be applied only to the beds below the unconformity. The fact that detailed work has now shown (1) that all the Laramie beds known on the Laramie Plains at the time of the adoption of the word "Laramie" are "Upper Laramie," (2) that, although they were believed to be entirely conformable with the underlying beds by all who had examined them, they are in fact separated from them by a great break, and hence that the statement of conformability in King's definition is without determinative value in this connection, because

> the base of the Upper Laramie, and included in the Fox Hills beds of Lower Laramie age which are exposed at this point, thus absolutely and conclusively limiting the Laramie at this point to the Upper Laramie.

based upon erroneous observations and conclusions, while proving that Cross's conclusion in this matter was incorrect, does not in any way detract from the great credit which is justly due him as the discoverer of this great break. Cross's error in this one particular of the restriction of the word "Laramie" to the lower beds was not due to his own observation, but to his acceptance of the work of others. This redefinition, instead of helping the already perplexed Laramie situation, but added one more complexity to it and resulted in the entirely incorrect and inappropriate application, to the Lower Laramie, of such terms as "Laramie proper," "original Laramie," "true Laramie."

The restriction of the term "Laramie" to the beds below the unconformity, based on Cross's studies in the Denver region, proves in its ultimate analysis to be an attempt to redefine a geologic term from the exposures and relations at a point almost 200 miles from the locality from which the geographic name was derived and at which the beds are most excellently exposed. This redefinition was based entirely on an abstract consideration of a statement based in part on erroneous observations, at a time when no critical re-examination had been made of the conditions in the region, whence the name was derived, and when nothing was known of the true relations in that area. We thus have the scientific anomaly of a geologic name derived from exposures in a certain region, all of which belong to one group of strata, redefined in a different region and applied to an entirely distinct group of beds. This is clearly indefensible and absolutely at variance with the fundamental principles of geologic nomenclature. It in effect gives a result which is no better than a lithologic term, and certainly not as appropriate. The whole case but emphasizes the absolute necessity of a geographic place origin for geologic names in order to finally guard against misinterpretations, incorrect statements, and conclusions by the authors of such names.

SUMMARY AND CONCLUSIONS

1. The name "Laramie" is derived from the Laramie Plains in eastern Wyoming. As commonly used in the early seventies, this included the plains region extending from the Front Range to and slightly beyond the North Platte River.

2. The most important locality on the Laramie Plains at this time was Carbon. It was not only a noted paleontological locality, but was the most important coal-mining town on the Union Pacific Railroad at that time. It was the only locality on the Laramie Plains where the King Survey critically examined and distinctly delimited the Laramie beds. The Hayden Survey recognized Laramie strata at another point on the Laramie Plains, Rock Creek, but regarded the Carbon locality, including its southern extension containing the plants labeled from "Medicine Bow stage station," as affording better and more complete exposures.

3. It was the practice of the Hayden and King surveys to name formations and groups from localities where the beds were regarded as typically exposed. While King and Hayden did not always definitely state that a name was derived from a certain locality, the source of the name can in all cases be completely inferred from the context. Thus King used Green River, Bridger, Uinta, Truckee, and other names without saying the name was derived from such and such a locality, while he distinctly states the source of Vermilion Creek, Weber, and other names. King's strong feeling in this matter of a type locality is shown by the fact that he refused to use the prior name "Wasatch" and adopted the new name "Vermilion Creek" simply because at what he considered Hayden's type locality the beds were not completely and typically exposed. The state of feeling at this time is further shown by the fact that the name "Laramie" was proposed and adopted as an exact synonym of Hayden's "Lignitic" as defined by him in Wyoming and Colorado. If merely a general term without a type locality was desired, the term "Lignitic" would have served all purposes. The change was clearly based on a recognition of the necessity of having a geographic type locality. From the above facts it follows irresistibly that the type locality of the Laramie is Carbon, on the Laramie Plains.

4. A critical consideration of investigations of Hayden and King parties in this region shows that the actual Laramie exposures studied by them are separated from the Cretaceous by an unconformity of great magnitude. At Carbon Hague particularly and minutely included only the beds above the break. Both Hayden and Hague regarded these beds as entirely conformable with those beneath;

hence the statement by King that the Laramie beds are those which conformably overlie the Fox Hills, while correct according to the existing knowledge, is not correct at the type locality, and therefore without determinative value in this connection. It but illustrates anew the absolute necessity of a type locality to afford means of finally and conclusively correcting any inaccurate statements or conclusions of the author or authors of a geologic name. Strictly considered, the term "Laramie" therefore can appropriately be applied only to the beds above the great unconformity and—fixing an upper limit in part from our present knowledge—below the Fort Union.[1]

5. The attempt to redefine the term "Laramie" from the exposures in the Denver region, some 200 miles from the type locality, is therefore not defensible. It results in the scientific anomaly of applying the term "Laramie" to a series of beds entirely distinct from those at the type locality on which the name was based. It completely robs the name of all geographical significance, and gives to it even less meaning or appropriateness than a mere lithologic term such as "Lignitic."

6. While strictly speaking the name "Laramie" can be appropriately applied only to the upper beds (Upper Laramie), and it cannot with any propriety be restricted to the lower beds (Lower Laramie), the consideration that it was proposed for the beds between the Wasatch and the marine Montana Cretaceous, and has been most commonly and extensively used in this broad sense, has led to the suggestion that the retention of the name in this original sense will cause the least confusion, and that it therefore might be expedient to define the Laramie as that series of beds occurring between the marine Montana Cretaceous and the Fort Union.

[1] At Evanston there are several reasons for believing that the base of the Wasatch of Hayden contains representatives of the Fort Union, Puerco, and Terrejon. Between the Laramie and the Coryphodon-bearing Wasatch are some 4,000 feet of strata separated from the Coryphodon-bearing beds by an unconformity. At Black Buttes beds now known to be Fort Union (Knowlton, *Bulletin of the Geological Society of America*, Vol. VIII [1896], p. 145) were referred by King to the Vermilion Creek. It therefore seems not only logical, but in accord with the original usage, to define the upper limit of the Laramie as the Fort Union. The Washakie beds which Hayden regarded as, in this region, limiting the Lignitic above (*Third Annual Report*, U. S. Geological Survey, Colorado, New Mexico, 1869, p. 90) and which were included by King in his Vermilion Creek, are the beds from which Knowlton reports distinctive Fort Union plants at Black Buttes.

In connection with this suggestion of expediency, it should be pointed out that the continued use of this term in the "catchall" sense is wholly at variance with the abundance of strong and wholly logical reasons for the restriction of the term "Laramie" to the "Upper Laramie" shown by the historical considerations already presented. If the point of confusion is regarded as one of great importance, it might be worth while considering the entire abandonment of the term "Laramie."

In either case a new name is required for the beds here referred to as Lower Laramie. Many considerations suggest that this name should come from the region of the Laramie Plains. This would be historically appropriate in many ways, and would result in placing the type locality of both the upper and the lower portions of the beds which have been called Laramie in the broad sense, in the same section. There are reasons for believing that the enormous development of Lower Laramie beds in the western part of the Laramie Plains near the mouth of the Medicine Bow River, or, as it is more commonly called by the local people, "The Bow," where there is relatively very little evidence of a break between the upper and lower beds, more completely represents the Laramie deposition than at any other point now known. These considerations make the "Bow formation" or "group" a very appropriate designation for these lower beds. On the other hand, the fact that the region of Golden has been made classic in connection with the "Laramie problem" by the studies of Cross, Eldridge, Knowlton, and others, raises the question whether the name "Golden formation" or "group" might not be a more appropriate name.

The discovery of this great unconformity at all points that have been critically examined over an area 1,000 miles north and south and 250 miles east and west, the fact that it occurs on both the east and west sides of the Front Range of the Rocky Mountains, and its great magnitude, all make it one of the important mile-posts in the geologic history of western North America. All these considerations suggest anew the first conclusion of Cross in the Denver region that this unconformity marks the dividing line between the Cretaceous and Eocene in this region. On this basis the arrangement of groups immediately above and below the great break would be as follows:

Lower Tertiary or Eocene	Green River	Wasatch
	Knight or Coryphodon beds[1]	
	Fort Union (Puerco and Terrejon)[2]	
	Laramie	
	Unconformity	
Upper Cretaceous or Platte series	"Lower Laramie"	
	Montana	
	Colorado	

[1] The name "Knight" has been proposed for the upper part of the Wasatch containing Coryphodon remains. It is taken from Knight Station, a point near the locality where fossils belonging to this genus were first found in North America, and where the typical upper Wasatch is extremely well developed. Certain considerations suggest that the Knight formation may be an exact synonym of King's Vermilion Creek formation, but as the writer has not had the opportunity to examine King's type section he has proposed the provisional name "Knight" pending a study of the Vermilion Creek section. See *Professional Paper 56*, 1907, pp. 87–89, 92–96.

[2] In the Evanston section, between the beds belonging to the Laramie (Carbon) group and the Coryphodon-bearing Wasatch, are 4,000 feet of strata which have the stratigraphic position of the Fort Union and Puerco. These are here separated from the Coryphodon-bearing portion of the Wasatch by an unconformity of much less magnitude and importance than that at the base of the Laramie (Carbon) beds.

THE CHARACTERISTICS OF VARIOUS TYPES OF CONGLOMERATES[1]

GEORGE R. MANSFIELD
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In the prosecution of a recent study of the Roxbury Conglomerate (Boston, Mass.), the writer found himself in need of criteria by which to determine the mode of origin of that formation. A critical examination was therefore made of the published descriptions of conglomerates in many parts of the world and belonging to many geological ages, in the hope of discovering characteristics sufficiently marked to distinguish one type from another. The data collected and the conclusions derived therefrom have recently been published in detail.[2] The present paper is a brief summary of the results of the investigation.

Five general types of conglomerate were considered, namely: marine, fluviatile, estuarine, lacustrine, and glacial. In addition to these, another type was studied, commonly known as crush-conglomerate, but really pseudo-conglomeratic in its nature. The fact was recognized that many conglomerates are the product of the combined action of several conglomerate-forming processes, but the results of each process were classified separately.

Among the formations taken under consideration were: the Cretaceous formation of Texas, as described by Hill;[3] the Pottsville Conglomerate; non-marine formations in India, Persia, Great Britain, and the United States; the Devonian of Pennsylvania and Maryland, as described by Willis;[4] the Newark formation as described by Russell;[5] glacial deposits of the Quaternary period in the United States and Europe; ancient glacial deposits in India, Australia, South Africa, and Norway; and crush-conglomerates in the Isle of Man and Argyllshire.

[1] Read before the Geological Society of America, December 28, 1906, New York.

[2] Museum of Comparative Zoölogy, *Bulletin No. XLIX*, Geological Series, 8, 1906.

[3] R. T. Hill, U S. Geological Survey, *Twenty-first Annual Report*, 1901, pt. 7.

[4] Maryland Geological Survey, 1902, Vol. IV, pp. 21–93.

[5] U. S. Geological Survey, *Bulletin No. 85*, 1892.

The data collected from these various sources were arranged in accordance with the following scheme:

Matrix.—Kind of material; size of grains (coarse or fine, uniform or varied); shape of grains (angular, subangular, or rounded); arrangement of grains (orderly or disorderly, well stratified, rudely stratified, or unstratified); cement (argillaceous, siliceous, calcareous, or ferruginous).

Pebbles.—Kind of material; size of pebbles (large or small, uniform or varied, gradation in any particular direction); markings (facets, polish, striation); deformation (distortion, tension cracks, fracture); arrangement (well stratified, rudely stratified, unstratified).

Color.—General tone of the rock; relations to matrix; relations to pebbles.

Characteristics of bedding.—Uniform series grading into finer beds, thickness and extent; variable series (lenses of coarser and finer materials, false-bedding and local unconformities, ripple-markings, sun-cracks, raindrop-impressions, or organic markings), thickness and extent.

Relations to subjacent rocks.—Conformable; nature of the underlying series; unconformable; eroded surface deeply disintegrated; eroded surface of relatively fresh rock unglaciated; eroded surface relatively fresh rock glaciated.

The matrices of the various types of conglomerates have not been very fully described. According to Geikie the small particles of detritus are generally less well rounded than those of greater dimensions.[1] This is doubtless true of all water-laid deposits. The evidence collected appears to show that the matrices of marine conglomerates tend to consist of clean sands fairly well sorted and often cross-stratified. Willis states of beach deposits that the "sand is clean and characterized by marked and irregular cross-bedding."[2] Russell, referring to the incrustation of the grains in certain ferruginous deposits, remarks that if the débris had been deposited in the ocean and exposed to the action of waves and currents, the sands would have been more thoroughly assorted than we now find them, and also that the attrition produced by the waves under such circumstances would have scoured off the incrustation of ferric oxide.[3] Dutton, too, emphasizes the more thoroughly assorted condition of marine sediments as opposed to fluviatile deposits. Of the latter he states that material of all sorts is deposited everywhere, yet with a tendency to

[1] *Text-Book of Geology*, 4th ed., Vol. I, p. 162.

[2] *Journal of Geology*, Vol. I (1893), p. 487.

[3] U. S. Geological Survey, *Bulletin No. 52*, 1889, p. 45.

sorting.[1] Probably the littoral deposits of lakes would approach marine deposits in uniformity of size and arrangement of particles, but with the absence of tides it is doubtful if these characteristics would be in general so highly developed.

Estuarine deposits are seen to consist in the main of mixtures of sand and clay, not very well assorted, but relatively fine. The matrices of crush-conglomerates would doubtless present much diversity in the size and shape, but not in the material, of their particles. Probably glacial deposits display the greatest variation in the character of the finer fragments that constitute their matrices. Fluviatile deposits may often approach them in heterogeneity of material and arrangement, and in angularity of individual particles. One minute distinction may, however, be noticed. In the case of small fluviatile fragments, which are only slightly rounded, the attrition will probably be equally developed on all corners or edges. In the case of similar glacial fragments, as shown by the microscopic study of the Dwyka conglomerate, one edge or corner of a particle may be smoothed or rounded, while other corners or edges remain sharply angular.

The evidence thus far collected goes to show that the pebbles of marine and lacustrine conglomerates tend to be well sorted and well rounded, though they may be subangular in proximity to their sources. Shrubsole, noting the way in which pebbles on a beach slip over each other with the recession of each wave, remarks: "The pebbles become as a rule symmetrical and lose all traces of angularity."[2] Estuarine pebbles tend to be but imperfectly sorted and rounded, and fluviatile pebbles may show all stages from confused heaps to well-stratified beds and from well-rounded forms to almost complete angularity. The difference between marine and fluviatile pebbles is thus expressed by Dutton:

> Attrition [in the fluviatile conglomerates of the high plateaus] is not ordinarily extreme. In most cases it is enough to indicate that the fragments are really abraded, though with no great loss of substance. The stones of subaqueous conglomerates, on the contrary, are always much worn and rounded. Again, the sizes of the stones [in the fluviatile conglomerate] range from a fraction of a cubic inch to several cubic feet; in rare instances to more than a cubic yard.[3]

[1] *High Plateaus of Utah* (Washington, 1880), p. 220.

[2] *Quarterly Journal of the Geological Society*, Vol. LIX (1903), p. 315.

[3] *Loc. cit.*, p. 224.

In crush-conglomerates the shapes and sizes are variable, depending on the character of the rocks crushed, and on the character and amount of the deforming force. No doubt the pebbles would often be distorted and contain fracture planes and tension cracks. Glacial pebbles are characterized by variety in composition, size, and shape. Their sizes and shapes may, however, be so successfully imitated by bowlders and pebbles of fluviatile origin that it is only when the fragments are seen to bear the characteristic glacial striae, or to be intimately associated with stones that are so marked, that their glacial nature can be regarded as established. Even here caution is needed; for in landslides or mud flows, or by the action of shore- or river-ice, striated pebbles may be produced, which closely resemble those developed by glacial action.

While the evidence shows that marine conglomerates are sometimes ferruginous, the trend of opinion seems to be that such rocks are not, as a rule, highly colored. According to Russell, observations show that lacustrine sediments are usually not red.[1] The evidence found with reference to the color of estuarine deposits is insufficient to make any general statement; they are, however, often considered to have a tendency toward a red color. Some of the fluviatile deposits studied are shown to have highly colored or purplish zones. Strahan, speaking of the characteristics of continental formations, says they have a common tendency to a red color.[2] Crush-conglomerates, being induced as secondary structures in rocks already formed, partake of whatever color the parent rock may have possessed. Glacial conglomerates, as a rule, appear not to be highly colored, though the Australian bowlder-beds are described as containing reddish-brown members. Red color is therefore not a distinctive characteristic of any particular type of conglomerate formation, but it may be said to be more common in the fluviatile and perhaps in the estuarine types than among the other kinds of conglomerate.

Marine formations have been found to possess, on the whole, the most uniform bedding; while glacial formations exhibit the least developed and perhaps the most irregular stratification. Lacustrine and estuarine formations tend to resemble those of marine origin,

[1] U. S. Geological Survey, *Bulletin No. 52*, 1889, p. 47.

[2] *Quarterly Journal of the Geological Society*, 1897, pp. 143, 144.

while fluviatile formations may be well stratified, or, on the other hand, may so closely simulate heterogeneous glacial accumulations as to make their origin uncertain: witness the discussion of the Midland Pebble Beds of the Old Red Sandstone. Cross-stratification and lenticular masses of coarser and finer material are common in all these types, but in the marine type the long axes of the lenses are more frequently parallel to the shore line—that is, to the original strike of the rocks; while in the case of fluviatile accumulations the long axes of the lenses are parallel to the courses of the stream threads by which they were deposited—that is, to the original dip of the rocks. All water-laid deposits appear to increase in thickness and coarseness toward their source of supply. Marine action, however, tends to produce sheets of relatively uniform thickness over wide areas, while fluviatile action tends to produce interwoven linear bundles of coarser and finer materials, which may attain great thickness in the aggregate over limited areas, but which thin out more rapidly than is the case with marine deposits. Other differences are cited by Strahan in his discussion of continental deposits. He states that the latter are not only unequal, but alternate with erosion, so that fragments of one bed are included as pebbles in another; that they rarely contain marine organisms or such strata as usually compose marine formations, but that drifted plant remains are not uncommon, and that such limestones as occur consist, when unaltered, of amorphous carbonate of lime and not of organic remains.[1] Current markings, sun-cracks, and foot-prints, or other impressions common on exposed mud-flats, are frequent in estuarine and probably in fluviatile or lacustrine deposits, but do not ordinarily occur in marine formations.

In crush-conglomerates no true bedding appears, and all traces of the original bedding may have been destroyed. The bedding of ice-laid deposits is very obscure, and that of fluvio-glacial deposits merges into that of true fluviatile deposits, so that little or no distinction can be drawn.

As regards the relations of conglomerates to subjacent rocks, the main fact brought out by the investigation is that those formations of any age, that have been proved to be glacial, have been found to rest upon striated rock surfaces. The possession of heterogeneous

[1] *Loc. cit.*

structure, irregular and striated pebbles, while furnishing strong evidence of glacial action, cannot be considered as conclusive proof, for such structures and forms may be produced in other ways. When, however, such forms are found to rest upon a smoothly polished and striated rock surface, the weight of evidence is so great that no other explanation can be accepted.

To summarize: Marine sediments exhibit, on the whole, the greatest uniformity of composition and the most orderly arrangement of materials, while glacial deposits display the opposite characteristics. Lacustrine, estuarine, and fluviatile accumulations attain intermediate degrees of uniformity. Each of the various types of conglomerate possesses features that are shared to some extent by other types. Thus there is no single feature which in itself distinguishes any particular kind of conglomerate. It is only when a number of features of one type are grouped and compared with a similar group of another type that definite distinctions can be made. Such a comparison is attempted in the accompanying tabular summary.

RESTORATION OF DIADECTES

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In 1905 the writer published in the *Journal of Geology* (Vol. XIII, No. 2) a description and discussion of the genus *Diadectes* Cope, based on several specimens forming part of the collection of the University of Chicago, and especially upon specimen No. 1075. More prolonged study and the discovery of several additional specimens make it possible to attempt a restoration. It is unfortunate that the species to which this specimen belongs cannot be determined. The specific characterization of members of this genus has been made entirely upon the teeth, and in this specimen the jaws are so tightly closed that their form cannot be made out. The only parts of the restoration not based upon No. 1075 are the feet, the distal ends of the lower-limb bones, the exact form of the posterior lumbar ribs, and the number of the caudal vertebrae. The form and proportions of the lower-limb bones have been determined from other specimens, and the shortness of the tail has been verified. The general character and proportions of the feet are also known from other specimens, as is the exact shape of many of the bones composing them; it is probable that the feet are somewhat too small in the restoration.

The restoration is one-sixth natural size; the animal, it is thus seen, was not far from three feet, six inches in length. This is by no means the largest representative of the genus, since another specimen known to the writer is nearly one-third larger.

The skull is relatively large and clumsy, set closely on the heavy spinal column, with practically no neck. It is noticeable that the heavy lower jaws hang as low as the sternum, giving the animal a bodily habit strikingly like that of the Stegocephalia. The vertebral column is very heavy, and its vertebrae are closely interlocked. The ribs are broad and heavy in the thoracic region, and are found on all the presacral vertebrae, even the atlas. No abdominal ribs have been found in any specimen of the genus, nor of the related genus

Empedias, but it seems very probable that they were present, both because of the prone attitude of the animal, and of its probable ancestral position as regards the Chelonia. It will be of the utmost interest to determine the presence and form of the abdominal ribs, if there be such.

The limbs are remarkably stout and short, with prominent rugosities for the attachment of powerful muscles. The feet are less well known, but the form of the known carpal and tarsal bones, and the shape of the phalanges, indicate a loosely knit foot, relatively broad and clumsy. The general form of the carpal and tarsal bones seems to have been similar to that of the Pariotichidae and the Pelycosauria, though much less perfectly modeled. The terminal phalanges are short and semicircular, covered with strong rugosities (see *Journal of Geology*, Vol. XI, No. 4, Fig. 6, p. 400); it is evident that there were no powerful claws, as in the pelycosaurs, but rather broad and clumsy ones. The most remarkable feature of the skeleton is the presence of plates overlying the first five dorsal ribs. As shown in Fig. 2, the first of these is very small, the second one far larger, and the succeeding three relatively narrow and high. They overlie the ribs directly,

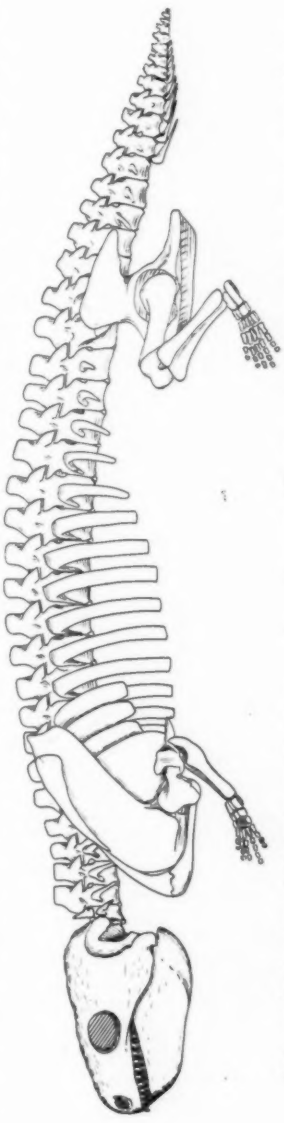

FIG. 1.—Restoration of *Diadectes*, sp., based on specimen No. 1075, University of Chicago collection. The feet are based on imperfect feet of other specimens. ×⅛.

and overlap each other from before backward. Two specimens show the presence of these plates in the position of the restoration, but there are no traces of others on the sides of the ribs or on the summits of the neural spines.

The position of the plates below the scapula is anomolous but there seems no escape from the conclusion that they are restored in the natural position; if the animal was very broad and low, grotesquely so, then the pectoral girdle might have touched only the outer ends of the ribs and the plates might have lain above the girdle; but the condition of the specimen forbids such a conclusion. The pectoral girdle is exceptionally well preserved and free from distortion, the bones are closely articulated and in their proper positions; the whole pectoral girdle has the form of a narrow U with the bottom forward. In fact the animal was distinctly narrow chested. There seems no possibility that crushing could have forced the plates into this position. This is perhaps one of the greatest arguments against the position of the Diadectids as ancestral to the turtles. Cope describes the pectoral girdle of *Otocoelus* and *Conodectes* as internal to the dermal plates which are however much larger proportionally than in the Diadectids.

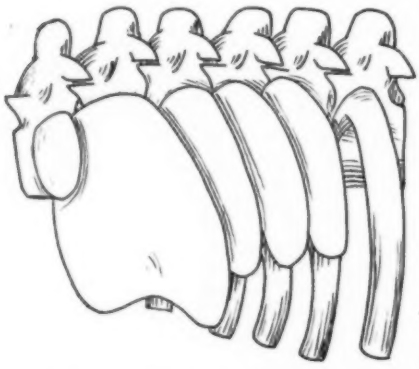

FIG. 2.—Six anterior dorsal vertebrae of *Diadectes*, sp., showing the form and position of the plates overlying the ribs. Specimen No. 1075, University of Chicago collection. ×½.

The assemblage of characters shown in the restoration seems to bear out the suggestion made in the previous paper (*loc. cit.*) that the Diadectids are perhaps the nearest to the turtles of the forms now known. The powerful head and jaws, with their numerous testudinate characters, the strong thoracic guard formed by the great scapula with its clavicle, cleithrum, and interclavicle; the short, powerful

limbs; the loosely knit splay feet, with their ill-developed terminal phalanges, all give an impression of a compact body lying close to the ground, and moving with a sprawling gait, much as in the turtles. The compactness of the body and the strong limb-bones led Cope to suggest that these animals were perhaps fossorial; but the character of the feet seems to preclude any such possibility. They must have been more like the great stegocephalians, but without their carnivorous habits—lowly, sluggish, inoffensive herbivorous reptiles, clad in an armor of plate to protect them from the fiercely carnivorous pelycosaurs.

DOME STRUCTURE IN CONGLOMERATE[1]

RALPH ARNOLD

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LOCATION AND COMPOSITION OF THE DOMES

On the flanks of Eagle Rock Valley, two miles west of Pasadena, Cal., are several dome-shaped structures developed in conglomerate. They resemble in a general way the granite domes of the Sierra Nevada, but are much smaller and also less isolated as regards the surrounding topography. The conglomerate is of lower Miocene age, is quite regularly bedded, somewhat tilted, and consists of sand pebbles and boulders of the granite, diorite, gabbro, gneiss, and other crystalline rocks which form the San Gabriel Mountains to the north. Some of the boulders are as much as 6 feet in diameter, although the average are not over 3 or 4 inches; some of the layers are little more than coarse pebbly sandstone.

EAGLE ROCK

The largest and most perfect example of a dome is found at the east end of the valley, and is called Eagle Rock. Fig. 1 is a view of Eagle Rock as seen from the southwest, and shows its position with respect to the surrounding topography. The "eagle" may also be seen on its 80-foot precipitous west face. The hills west and south of the rock are of conglomerate, similar to, except softer than, that composing the dome, and dipping in the same direction. The hills immediately to the north—to the left of it in this view—are of crys-

[1] Read before the Geological Society of America, December 28, 1906, and published by permission of the Director, U. S. Geological Survey.

talline rocks, and are separated from the conglomerate by a fault, the latter, however, having no apparent relation to the origin of the dome. The bedding of the conglomerate is plainly marked by the lines of protruding pebbles and cobbles on the south side of the rock.

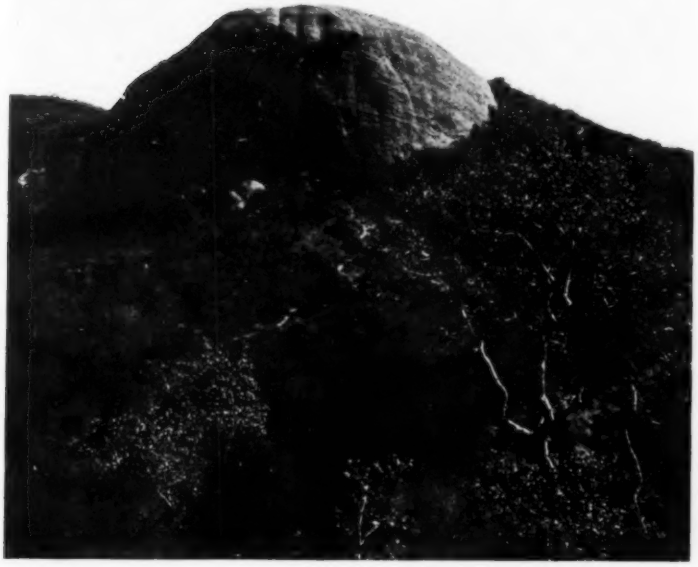

FIG. 1.—View of Eagle Rock, a conglomerate dome, seen from the west, showing its relation to the surrounding topography: front elevation 80 feet.

The blocks immediately in front are fragments of the layer or shell, the remaining parts of which form the prominent overhanging V-shaped block. This layer was from six to eight feet through, and possibly more. A crack extends upward under the north arch of the overhanging block but none is present under the south arch, the block and adjacent dome face meeting in a solid concave junction. The

iron stains seen on the west face of the rock in this view, and in Fig. 3, emanate from the cracks under the scales.

A view of Eagle Rock from the south is shown in Fig. 2. This picture presents a profile of its west face, showing the solid joint between overhanging block and nearly perpendicular rock face; also the rough, pebble-covered south wall of the dome. The top of the rock conforms approximately to the dip of the conglomerate, and

FIG. 2.—Eagle Rock, viewed from the south, showing bedding in the conglomerate, and a profile of the west face.

is devoid of vegetation with the exception of a patch or two of moss and a few straggling shrubs.

The north side of the dome, shown in Fig. 3, is penetrated by two caves which have been formed by the weathering-out of the incoherent portions of the rock. These caves are the result of phenomena different from those resulting in the scales and dome surfaces. The walls of the caves are concave inward, somewhat softer than the exposed surfaces of the dome; the bottoms of the caves slope gently outward. Beneath the caves will be noticed several arches similar in a general way to the great arch. These are of various sizes as

regards length and thickness, and represent the lower edges of more or less well-developed scales. Small scales transverse to the larger ones are often developed across the lower portions of the latter, the line of parting always beginning at the interior surface of the larger scale and extending up into it toward its outer surface. An example of such a secondary scale is shown in Fig. 4, which is a profile of the north face of Eagle Rock. Many other scales, some of them from

FIG. 3.—Near view of Eagle Rock, from the north, showing caves, some smaller arches, and profile of the west face.

one to six inches thick, and some thinner, but most of them inconspicuous in the photograph, are developed over the steeply sloping faces of the rock. It is a very significant fact that the interior walls of the caves, which are practically dry at all times, are not scaling off; neither is the south face, nor the top of the dome.

OTHER EXAMPLES

At the western end of the Eagle Rock Valley are several prominent examples of dome structure in conglomerate similar to that composing

Eagle Rock. Some of these are little more than huge boulders, and one of them is only about ten feet in diameter. This last one, however, presents a very characteristic dome surface, with accompanying scales and arches on three sides, east, north, and west. In the vicinity of the small dome is the conglomerate exposure shown in Fig. 5. Taken as a whole it is but a small fraction of a complete dome, but it offers the best opportunity for detailed study of the phenomena of dome formation of any of the examples in this region. The view is looking north; the conglomerate dipping northeast. The surface bows over from a slope of 30° to one of approximately 60°. The overhanging block on the face of the dome is about four feet thick at its thickest point, and consists of hard, little-weathered conglomerate. The block thins toward the southeast (the right in the photograph), the crack under it narrowing proportionately at the same time.

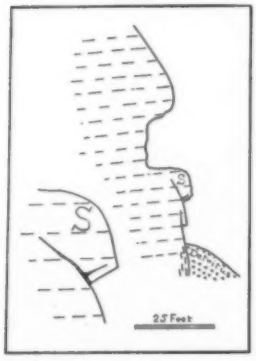

FIG. 4.—Profile of north face of Eagle Rock, with detail of scale at S, latter showing transverse crack in scale.

In direct contrast to this hard sheet is a 3-foot zone of weathered rock shown in detail in Fig. 6, which was taken looking west into the crack extending under the outer shell on the left in Fig. 5. The hammer stands vertical, the handle resting on the hard surface of the new dome face, the head resting against the weathered zone, and the upper portion of the picture displaying the hard outer shell. The weathering process has resulted in the formation of a series of laminae (noticeable in the picture above the head of the hammer), from a small fraction of an inch to an inch in thickness extending approximately parallel to the dome surface. The planes separating the laminae pass through the conglomerate in most cases irrespective of the composition and hardness of the component parts of the rock, appearing to cut the hard granitic cobbles as readily as the softer arkose matrix. An exception to this is the exceedingly hard aplite boulder seen on the extreme left of the photograph. An idealized profile of the dome-face just described is shown in Fig. 7.

It is worthy of note that domes are so far known to occur only in plutonic rocks or in a clastic rock made up entirely of material of plutonic origin. This is true probably because the coincidence of texture and mineral constitution, essential to the peculiar type of weathering causing the scaling process, is confined to plutonic rocks.

SUMMARY OF OBSERVATIONS

Concerning the scaling process itself in the conglomerate the following observed facts and the deductions drawn from some of them may be given:

FIG. 5.—Dome surface in conglomerate at western end of Eagle Rock Valley, viewed from the south, showing crevice under large scale.

1. The scales are not found on slopes of less than 30° or 40°, thus showing that the process is influenced by gravity.

2. The scales are almost entirely absent from the exposed southern faces and other portions of the rock, which are kept dry or practically dry, most of the time, indicating that moisture is a necessary agent in the process. The paucity of the scales on the surfaces most exposed to the sun argues against change in temperature being responsible for their formation.

3. The cracks separating the scales from the dome-face always penetrate upward, never downward, and approximately parallel the outer surface of the scale.

4. The incipient cracks are closely followed by a zone of weathering which often shows thin lamination parallel to the crack, and which, crumbling away, produces a crevice. The intensity of the weathering which goes on in this zone is often evidenced by the iron and other stains which emanate from the cracks and run down the surface of the dome.

PREVIOUS THEORIES REGARDING THE ORIGIN OF DOMES

Two general theories have been advanced in explanation of such peculiar structure, all heretofore, however, based upon observations of the development of domes in granite. Gilbert[1] states these theories thus:

"According to one theory the separation of the granite into curved plates is an original structure, antedating the sculpture of the country and determining the peculiarities of form. According to the other theory the structure originated subsequently to the form, and was caused by some reaction from the surface."

Becker,[2] Branner,[3] Dana,[4] Geikie,[5] G. P. Merrill,[6] Shaler,[7] Turner,[8] Gilbert,[9] and Chamberlin and Salisbury[10] support the latter theory, while Le Conte,[11] Muir,[12] Whitney,[13] Bonney,[14] and some German writers[15] are in favor of the first.

[1] *Bull. Geol. Soc. Am.*, Vol. XV, 1904, pp. 29, 30.

[2] *U. S. Geological Survey*, Monograph 13, pp. 70–72, 1888; *Tenth Ann. Rept. U. S. Geol. Surv.*, 1890, p. 142; *Bull. Geol. Soc. Am.*, Vol. II, 1891, p. 69.

[3] *Bull. Geol. Soc. Am.*, Vol. VII, 1896, p. 281.

[4] *Manual of Geology*, 1895, p. 127.

[5] *Textbook of Geology*, 1893, p. 348.

[6] *Rocks, Rock-Weathering and Soils*, 1897, pp. 180–184.

[7] *Proc. Bost. Soc. Nat. Hist.*, Vol. XII, p. 289.

[8] *Proc. Cal. Acad. Sci.*, 3rd ser., *Geology*, Vol. I, p. 315.

[9] *Loc. cit.*, pp. 30–34.

[10] "Processes and Their Results," *Geology*, Vol. I, 1904, pp. 41–46.

[11] *Elements of Geology*, 4th ed., pp. 283, 284.

[12] *Proc. Am. Assn. Adv. Sci.*, Vol. XXIII, pp. 61, 62.

[13] "Geol. Surv. Calif.," *Geology*, Vol. I, pp. 371, 372.

[14] *Quart. Jour. Geol. Soc. London*, Vol. XXXII, 1876, p. 149

[15] Turner, H. W., *loc. cit.*, p. 313.

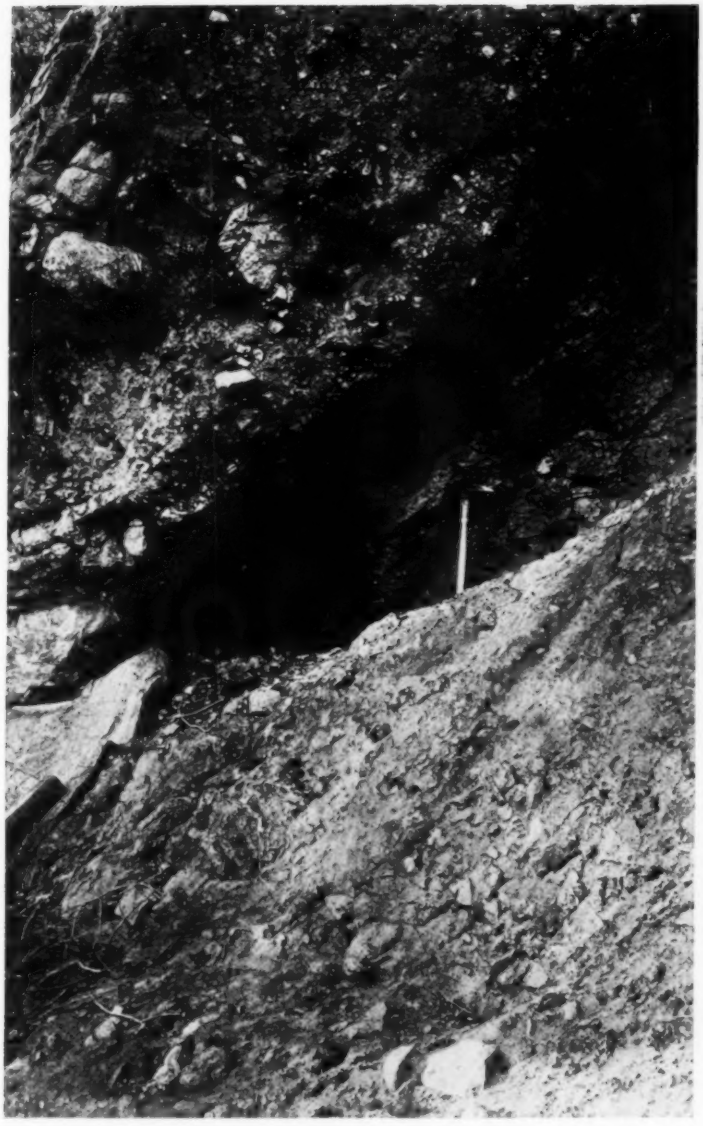

FIG. 6.—Detailed view of crevice shown in Fig. 5, looking west, showing lamination of the conglomerate in the weathered zone.

Those who support the theory of reaction from the surface differ as to the agent or agents which have brought about the result. Becker[1] believes the great granitic domes to be simply cases of exfoliation on a large scale, their regular curvature being due to the fact that, measured per unit volume, the surface exposed is in inverse ratio to the radius of curvature, so that the sharply curved surface weathers fastest. Furthermore he says:[2] "Weathering and abrasion proceed with a rapidity which increases with the surface exposed per unit volume. Hence these processes lead to minimum surfaces. Therefore, also, the mathematics of erosion is essentially identical with that of capillarity."

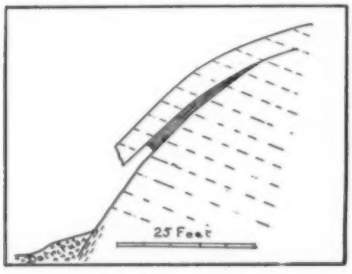

FIG. 7.—Section of dome at west end of Eagle Rock Valley, showing weathered zone below overhanging block.

Branner,[3] from observations in Brazil, expresses the opinion that the even annual and diurnal changes and the approximately even penetrations of these changes cause the rocks to exfoliate or to shell off in layers of even thickness like the coat of an onion. Merrill[4] attributes exfoliation largely to temperature changes, but considers the curved partings in the rock below the exfoliating surface as the result of torsional strains. Chamberlin and Salisbury[5] account for exfoliation on both a small and a large scale (including the dome structures of the Sierra Nevada) by great daily, rather than by great annual, changes in temperature causing expansion and contraction in the outer layers of the rock. They also consider the wedge work of ice effective in augmenting the scaling caused by expansion. This latter cause would necessarily be inoperative in that part of southern California in which Eagle Rock is located, for the temperature here seldom descends to 32° F.

[1] *Tenth Ann. Rept. U. S. Geol. Surv.*, 1890, p. 142.

[2] "Present Problems of Geophysics," *Science*, n. ser., Vol. XX, 1904, pp. 551, 552.

[3] *Loc. cit.*, p. 281.

[4] *Loc. cit.*, pp. 180–84.

[5] *Loc. cit.*, pp. 42–44.

Gilbert[1] suggests three processes, all of which, according to him, may be concerned in the formation of domes, viz.: (*a*) secular changes in temperature (he dismisses annual and diurnal changes because their influence penetrates but a small distance); (*b*) expansive force developed in weathering, and (*c*) dilation from unloading.

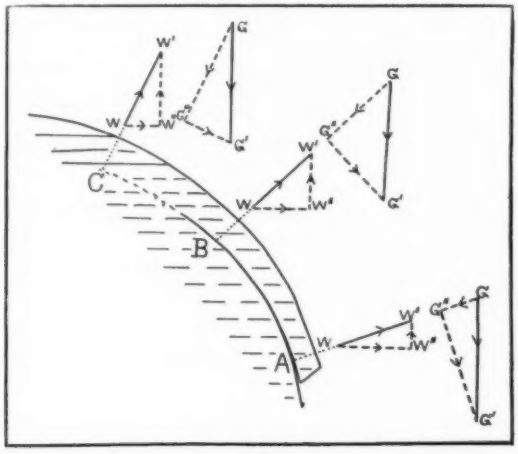

FIG. 8.—Graphic representation of some of the forces effective in dome formation.

WW′=expansive force due to weathering, acting at A, B, and C.

GG′=weight of overhanging or loosened block effective at A, B, and C.

WW′−(GG″+cohesion and adhesion of conglomerate)=EF=effective force tending to formation of crack.

The component of EF acting in the direction WW″, and G″G′ tend to removal of loosened block; these two forces become less and less as the slope of the dome surface decreases, reaching the value zero at the point where the tangent to the surface is horizontal; where the tangent is vertical they have their maximum value of WW′ and GG′, respectively. The scaling process is, therefore, most effective on vertical faces, becoming less and less so as the faces approach the horizontal.

CONCLUSIONS REGARDING THE ORIGIN OF CONGLOMERATE DOMES

The conclusions reached by the writer, regarding the origin of the conglomerate domes just described, involve both of the two general theories previously given, and may be tentatively stated as follows:

In the first place they are locally hardened portions (gigantic concretions, if you please) of a practically homogeneous conglome-

[1] *Loc. cit.*, p. 32.

rate of plutonic rock material. After the ordinary process of erosion uncovers a sufficient surface of the indurated rock the dome structures are formed by a successive scaling-off of blocks, through the development of cracks approximately parallel to the steeply sloping surfaces. These cracks are probably due to expansive force developed by chemical reactions (weathering) produced largely by moisture, the moisture passing upward by capillarity through the incipient cracks caused by expansion, and thus advancing the process. The cracks originate in positions advantageous to the accumulation or retention of the moisture producing the weathering, such, for instance as that occupied by the detrital material at the base of the slope or in the angle between overhanging blocks and the new dome surface. The direction of the cracks is determined by the configuration of the rock surface, being approximately parallel to it, the departures from strict parallelism being of such a nature as to omit angles and other features of irregularity. This parallelism to the surface is due to the expansive force acting along lines of least resistance, which in this case are practically normal to the outer rock surface. The slope of the surface is the governing function in the removal of the scales because the components of gravity and of the expansive force tending to dislodge the separated scales is greater on steep slopes than on low, while the component of gravity tending to counteract the expansion due to weathering is correspondingly less on steep slopes, becoming greater as the angle of declivity lessens.

Fig. 8 illustrates graphically the two principal forces (expansive force due to weathering, and gravity) effective in dome formation. These forces are resolved into components at three different points on the dome surface, in order to make clear the last sentence in the preceding paragraph.

PRE-WISCONSIN DRIFT IN THE FINGER LAKE REGION OF NEW YORK

FRANK CARNEY

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INTRODUCTION

With old drift on Long Island,[1] in New Jersey,[2] and in northwestern Pennsylvania,[3] it is very likely that a line of old drift should connect these areas. If, however, these localities of old drift represent ice-work from separate dispersion centers, then the re-entrant

[1] J. B. Woodworth, *New York State Museum Bulletin 48* (1901), pp. 618–70; M. L. Fuller, *American Geologist*, Vol. XXXII (1903), pp. 308–12; A. C. Veatch, *Journal of Geology*, Vol. XI (1903), pp. 762–76.

[2] R. D. Salisbury, Geological Survey of New Jersey, *Annual Report for 1893*, pp. 73, etc.; Vol. V (1902), pp. 187–89; 751–82.

[3] F. Leverett, *Monograph XLI*, U. S. Geological Survey (1902), p. 228; L. H. Woolsey, *Beaver Folio*, No. 134 (Pennsylvania), U. S. Geological Survey (1905), p. 7.

angle not covered by this drift might include much of New York state; but this supposition is hardly in harmony with accepted facts concerning the centers of ice-dispersion. Theoretical consideration, therefore, leads to the conclusion that in the Finger Lake region of New York the late Wisconsin drift sheet covers at least the ice-erosion remnants of older drift. Students of glacial geology have already tentatively presumed earlier glaciation in this region.[1]

That there has not already been reported some observed evidence of pre-Wisconsin drift in the Finger Lake region is doubtless due to one of two causes: workers may have felt that such drift should be highly weathered; or that at this distance north of the ice-margin erosion was so vigorous as to have removed the earlier drift. In all probability ice-erosion has removed most of the weathered horizon of the old drift, mingling it so thoroughly with fresh débris that it is not easily identified. In walking over the fields of the lake country one notes the presence of small bowlders which are very much weathered, bowlders that remind him of the general condition of stones in the areas of old drift; this is the most pertinent suggestion of the earlier glaciation of this region.

PRE-WISCONSIN DRIFT IN GENERAL

The older drift sheets have been studied more thoroughly in the Mississippi basin than elsewhere; their chronological sequence is generally established on the degree of weathering exhibited. In the case of the Sub-Aftonian[2] and the Iowan,[3] the lithological content is made a discriminating feature; the absence of water-laid material is a feature usually emphasized in describing the Kansan drift,[4] whereas the blue or blue-gray color of the unweathered Illinoian is pointed out.[5] Where the formations of different sheets of drift are superposed, the distinctions may be more accurately recorded; but good sections of this imbrication are rare. Some contact sections, all from

[1] R. S. Tarr, *Journal of Geology*, Vol. XIV (1906), pp. 18, 19; *Bulletin of the Geological Society of America*, Vol. XVI (1905), p. 217; H. L. Fairchild, *ibid.*, p. 66.

[2] W. J. McGee, U. S. Geological Survey, *Eleventh Annual Report* (1891), p. 497.

[3] Chamberlin and Salisbury, *Geology*, Vol. III (1906), p. 384.

[4] *Ibid.*, p. 389.

[5] F. Leverett, *Monograph XXXVIII*, U. S. Geological Survey (1899), p. 28; *Monograph XLI* (1902), p. 272.

the Mississippi valley, are shown in Chamberlin and Salisbury, *Geology*, Vol. III, pp. 385–88.

Descriptions of old drift in western Pennsylvania and in New Jersey are perhaps more pertinent to the New York area. The old deposits in Pennsylvania, described by Leverett, are very stony, the pebbles usually showing water action; the bowlders are small and mostly of local origin; only a small amount of clay is present; there is

FIG. 1.—Southern portion of Bluff Point viewed from the east. The break or terrace in the frontal slope is a cusp which apparently correlates with Fairchild's Wayne overflow stage of glacial lake Hammondsport.

slight evidence of bedding; the highly weathered condition of the drift, and the great amount of erosion it has suffered, are its conspicuous characteristics.[1]

The earlier drift in New Jersey is thus described: "The outer and older drift is deeply weathered from top to bottom, even where it has a thickness of thirty feet, the greatest thickness it is known to possess. Its stones, so far as they are of decomposable rock, are decayed.

[1] *Loc. cit.*, pp. 228, 229, 235.

From it most of the calcareous matter has been leached."[1] "The constitution of the drift is, in a general way, comparable to that of the younger drift. It contains materials of all grades, from huge bowlders to fine clay." "Limestone is rarely present. When the drift occurs in quantity, glaciated stones are by no means rare."[2] "It generally lacks all indication of structure, though foliation is to be seen in some of the deeper exposures." "In its constitution, and in the relations of its constituents, the drift corresponds with till."[3]

It should be noted, however, that Salisbury does not find the extramorainic drift in New Jersey uniform in the stage of weathering attained;[4] for this reason he suggests that, while most of it probably corresponds to the Kansan, it is possible that a younger pre-Wisconsin drift may be represented.[5]

Geographical factor.—The above descriptions of drifts pertain to deposits more or less distant from central New York. The diversity in the stratigraphy and topography of northern North America introduces other considerations that may render these descriptions only partly applicable to other regions. Similarity of glacial deposits elsewhere may result only from identity (*a*) in the stratigraphical terranes which furnished the débris; (*b*) in the period and conditions of weathering to which the débris was later exposed; (*c*) in the successions of ice-invasions; and (*d*) in the distance of the sections being compared from the termination of the particular sheet in question. It is evident, therefore, that in New England, New York, Pennsylvania, and New Jersey specific drift-sheets may have somewhat different features than have been reported by investigators elsewhere.

TOPOGRAPHIC CONTROL OF THE EROSION AND DEPOSITION OF DRIFT

In general.—It is probable that the main dissection lines of the Finger Lake area even before the earliest glaciation were north-south valleys; the troughs of the present lakes, their tributaries, primary, secondary, and lesser, had developed a variety of transverse valleys. So in whatever direction the ice-mass moved there must have been localities, of rather limited extent, where ice-erosion was less active;

[1] R. D. Salisbury, *Glacial Geology*, Geological Survey of New Jersey, Vol. V (1902), p. 174.

[2] *Ibid.*, p. 188. [3] *Ibid.*, p. 757. [4] *Ibid.*, p. 769. [5] *Ibid.*, p. 782.

also localities where the deposition of ice-débris was more pronounced. The combined effects of glacial erosion by the different invasions has not removed all the residual soil, the regolith of preglacial weathering.[1] Nor would a succeeding ice-sheet carry off all the drift deposited by a preceding invasion. Therefore it remains to inquire into the conditions most favorable to the deposition, and least favorable to the ice-erosion of former drift-sheets.

FIG. 2.—An east-west section showing contact of the two drifts as exposed south of Dunning's Landing. The wavy, irregular line marks the upper surface of the blue till.

Deposition of drift.—Aside from the ground moraine, the thickness and irregularity of which attest the heterogeneously distributed load which is being carried by the retreating ice, the localized deposits of débris represent in the first place a reaction of climatic factors that cannot be specifically determined; and, in the second place, the

[1] H. L. Fairchild, *Bulletin of the Geological Society of America*, Vol. XVI (1905), pp. 53–55; R. S. Tarr, *American Geologist*, Vol. XXXIII (1904), p. 287, and F. Carney. The writer's unpublished notes on the Moravia (N. Y.) quadrangle afford further proof of the presence of preglacial weathered products in place.

influence of topography upon the detailed outline of the ice-front. Climatic control evidently occasioned the pulsations of halt and retreat marked by the irregularly spaced belts of thickened drift; while the distribution of drift within the belts themselves is due both to local topography and to the topography of the areas passed over, in so far as these areas have contributed to the load of the ice. Furthermore, the broader outlines of these irregularly spaced belts reflect the reaction of the larger topographic features and the general direction of ice-movement from the dispersion centers; in consequence of this we have the moraines of ice-lobes. It follows, then, that no satisfactory control can at present be announced for the spacing of these belts.

Nevertheless, the influence of topography upon the detailed expression of the drift within the belt admits of closer definition. We would refer particularly to the following three conditions: (1) In a uniformly level area the ice-front would be without pronounced re-entrant angles; the drift would have a correspondingly even front, while it might have a very irregular surface. This type of topography is apt also to impose its characteristics upon the drift itself, as may be seen in the prairie regions. (2) In a section where the major valleys approach a position transverse to the general direction of ice-movement, the drift is found massed in these valleys, especially on their iceward sides; while in the tributaries of these major valleys are moraine loops or dams. (3) If, however, the chief valleys approach a position parallel to the general direction of ice-movement, we find in them lateral moraines[1] blending into loops of drift in the bottoms of the valleys; while the secondary valleys may be partially clogged or buried with drift.

Erosion of drift.—With this distribution of drift there must have been differential erosional effects produced by a second invasion of ice. Rather slight modifications would be effected under condition (1). The work of another ice-sheet passing over such an area is compressive quite as much as erosive; the more evenly the original drift is distributed, the less obstruction it offers to the progress of later ice; whereas the weight of the overriding ice tends to compact this drift.

[1] R. S. Tarr, *Bulletin of the Geological Society of America*, Vol. XVI, pp. 218, 219.

During the interval of deglaciation, stream-channeling, in the featureless topography of condition (1), proceeded slowly, since, to some extent at least, the streams were consequent. But with a larger lapse of time between the periods of glaciation this surface may have attained the relief of mature dissection, when it would present to the ice of the next invasion an opportunity for more effective corrasive work.

Each succeeding invasion would remove less of the previously

FIG. 3.—Contact of the two drifts at Crosby. The broken line marks the upper surface of the compact blue till.

deposited drift; it seems very probable that the resultant of several glacial invasions of such featureless topography is somewhat aggradational. And the final form given this drift depends upon the width and spacing of the moraine belts, if the ice were subject to varying relations of feeding and melting; or upon the thickness of drift deposited in an extensive sheet in case the feeding and melting factors were about balanced, the melting being slightly the stronger of the two.

That the resulting forms due to the aggradational action of an ice-sheet overriding these two types of drift arrangement would not be identical seems reasonable.

The drift as described under condition (2) would suffer much less from a second invasion. The deposits in the major valleys—i. e., the valleys transverse to the direction in which the ice is moving—would be somewhat protected from erosion; the weight of the overriding ice would tend to indurate this drift. But the drift in valleys tributary to these, since they trend more in unison with the moving ice, must suffer much more from erosion. When such accumulations are rather thick, it is probable that a drumlinoid form is the resultant of degradation by a second invasion of ice, particularly in these tributary valleys.

The most marked erosional effects, however, are observed in the old drift as distributed under condition (3). These valleys accord with the direction of ice-movement; if they open toward the approaching ice, greater obstruction is offered to its progress, hence greater erosion results; if they lead away from the feeding ice, the disturbance of the adjacent material may not be so marked. In the former case—i. e., the northward flaring valleys—the older drift, if not eroded, is apt to be deeply buried because of the intense aggradational work of the valley lobes which characterized the margin of the waning ice-sheet. In the latter case the ice-erosion is less effective; the augmented ice-front drainage has degraded, shifted, or covered with later outwash the earlier deposits. The application of this principle probably varies inversely with the size or width of the valleys.

But the old drift in the minor valleys of condition (3) has suffered less from ice-erosion. The stage of development of these minor valleys, and their degree of transverseness to the moving ice, are important factors in controlling the extent of ice-erosion in them.

Furthermore, under all these conditions we should find more old drift preserved in areas where during either pre- or inter-glacial time the drainage has suffered rejuvenation. The chances of such old drift being later revealed is greater in the transverse drainage lines of condition (3).

INHERENT CHARACTERISTICS OF OLD DRIFT THUS PRESERVED

Compactness.—The obvious resistance which this old drift offers to stream- or wave-cutting is its most characteristic feature. The pressure of the overriding ice-sheet has not only rendered such drift very compact, but there should be seen, particularly where the original deposits were fine in texture, a foliation due to the pressure. Lamination also might be contemporaneous with the formation of the

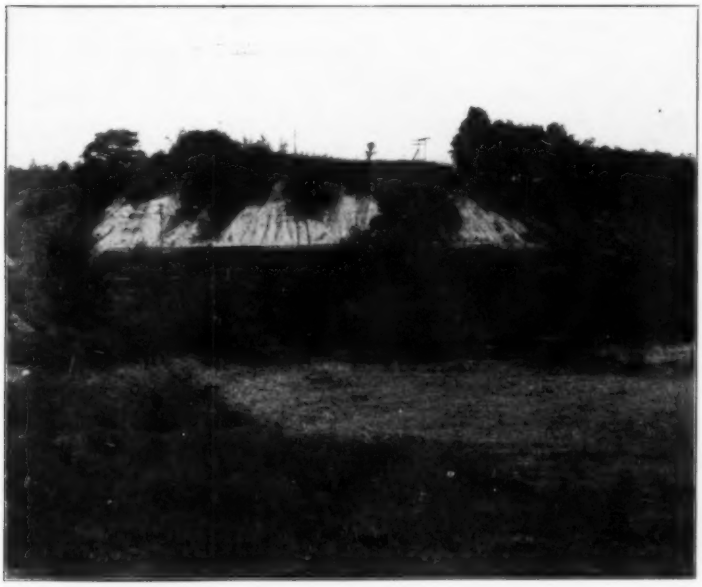

FIG. 4.—The horizon of the Wisconsin drift is fairly well defined by the vegetation; the steep bare slope consists of very compact bluish till.

deposits, but in any event it would be induced by great pressure. The effect of the superincumbent weight of a second ice-sheet should be noted, where the drift has been dissected into rather vertical cliffs, in the tendency of the pebbles and bowlders to overhang.

Color.—In the region under discussion ice-erosion has had, in general, favorable conditions for effectiveness. The highly weathered zone of an earlier drift-sheet would be most disturbed or eroded by

another invasion of ice, except in the case where ice-erosion had fallen short of the unweathered zone. The part of this earlier sheet remaining should have its original color, or at least the color which it had just previous to being overridden. Its present color need not necessarily be fresh or untarnished, but there is strong presumptive evidence that no color alteration has occurred since the retreat of the Wisconsin ice which furnished the débris for a protective burial of this older drift.

TOPOGRAPHY OF THE FINGER LAKE REGION

General statement.—The wide, prevailingly mature, lake-bearing valleys of central New York have received critical attention from workers in many lines of geology. Less attention, however, has been given to the more mature defunct valleys generally transverse to these. It is the unusual parallelism of the former, and their marked scenic beauty resulting from the variously interrupted drainage history, that impel the comment of even the untrained observer. These long valleys opening to the north were occupied during the waning stage of the ice-sheet by valley glaciers[1] or by valley lobes which were relatively broad—a condition due to the iceward slope of the valleys.

Topography favors both ice-erosion and ice-stream aggradation.—These conspicuous valleys, digital-like in arrangement, because of their general north-south trend, molded the basal ice of the deploying sheet into forms that expedited erosion. Furthermore, the fact that these valleys sloped toward the overriding wedges of ice facilitated the acquiring of a load which in turn augmented the erosive power of the ice up to the time when the amount of this load became so great that the basal ice lost in velocity; it then did little degradational work. In consequence of this differential erosion we find that approximately the southern thirds of these valleys are zones of ice-aggradation. Therefore Professor Tarr's 900-foot-contour upper limit of most active erosion[2] defines a plain which dips into the Allegheny Plateau. The present attitude of this plain of erosion embodies some post-glacial deformation due to warping; but, neglecting the effects of

[1] H. L. Fairchild, *American Journal of Science*, Vol. VII (1899), pp. 252, 253.

[2] *Popular Science Monthly*, Vol. LXVIII (1906), p. 389.

this warping,[1] it is not likely that the plane would define a surface even parallel to its original attitude. Concerning the relation which this part of our continent bore to sea-level while the Wisconsin ice-sheet was active, we have insufficient data to warrant any but very general conclusions.

It is evident, then, that so far as the north-south valleys are concerned, exposures of the old drift are more apt to be found in a belt skirting the zone of heavy drift in the southern parts of the valleys; northward from this hypothetical belt erosion may have been very active, tending to remove the earlier deposits; southward, aggraded glacial rubbish has probably covered these deposits.

Few of the quite mature transverse valleys belonging to an interrupted but well-developed drainage cycle, above alluded to, have been described.[2] The more nearly transverse to ice-movement such valleys lie, the less ice-erosion they are subject to. Subsequent invasions of ice presumably have not removed much of the residual rock waste that escaped the earliest glaciation; nor would an earlier deposit of drift suffer great erosion. Consequently, valleys of this type are best fitted for the preservation of pre-Wisconsin drift. In the area covered especially by this paper two segments of such valleys, one extending eastward from the vicinity of Branchport (Penn Yan Quadrangle), the other extending westward from Dresden (Ovid and Penn Yan Quadrangles), have been studied.

LOCATION AND DESCRIPTION OF THE PRE-WISCONSIN DRIFT IN QUESTION

First indication of such drift.—In the area from Skaneateles to Keuka Lake the writer has often noted the highly weathered condition of smaller bowlders both on the surface and in cuts in the drift. Later acquaintance with the older drift in Ohio has led him to give further attention to this observation. These scattered, rather rotten crystallines may or may not suggest drift of different ages.

[1] G. K. Gilbert, U. S. Geological Survey, *Eighteenth Annual Report* (1896–97), pp. 603–6; H. L. Fairchild, *Bulletin of the Geological Society of America*, Vol. X (1899), pp. 66–68.

[2] R. S. Tarr, *American Geologist*, Vol. XXXIII (1904), pp. 271–91; F. Carney, *Journal of Geography*, Vol. II (1903), pp. 115–24.

It is not likely that the first or even the second ice-invasion removed all the residual products of preglacial weathering. This much weathered material would constitute a larger part of the first than of any later drift-sheet. And from the fact that residual decay is noted beneath the Wisconsin drift[1] it follows that some preglacial weathered products have withstood several periods of ice-erosion.

Western slope of Bluff Point.—This elongated ridge, drumlin-like in outline and slopes, peninsula-like in reference to the arms of the lake,[2] rises about 715 feet above the level of Keuka Lake. Its longer axis is meridional (Fig. 1.). The striae below the 1,100-foot contour measure S.65°–28° W. So on the western slope of the bluff the work of the ice was dragging and plucking rather than abrading. But if these striae represent only the final ice-motion in the area, then the work of the glacier may have been more vigorous at an earlier stage. In any case, the striae indicate that this slope was leeward at least part of the time, hence the subdued erosion.

In the veneer of drift we note a conspicuous number of very weathered stones. These constituents in many instances are rotten, going to pieces under a blow of the hammer; others show in cross-section a surface altered zone, one-quarter to one-half inch wide. Even the pitted quartzite bowlders are not rare.

Eastern slope of Bluff Point.—On this opposite slope of the bluff a roadway leading northward from Dunning's Landing makes an exposure of highly weathered material just north of William T. Morris' cottage. This is the only section which suggests a concentration of rather uniformly altered drift constituents; neither the location nor the weathered condition of this exposure necessarily implies old drift.

About one-half mile south of Dunning's a recent stream channel reveals the contact of two distinct types of drift. The upper horizon is the familiar Wisconsin which here overlies a semi-indurated bluish till. This latter is fresh in comparison with the overlying Wisconsin which at this point is about 6 feet thick (Fig. 2.).

[1] H. L. Fairchild, *Bulletin of the Geological Society of America*, Vol. XVI (1905), pp. 64,65; R. S. Tarr, *American Geologist*, Vol. XXXIII (1904), p. 286.

[2] James Hall, "Geology of the Fourth District," *Natural History of New York*, Part IV (1843), p. 159.

Northward along this slope a similar arrangement of drifts was noted in three places.

On these steep slopes heavy rains and spring thaws open new channels cutting 10 feet to 15 feet in a few seasons. The Wisconsin drift is easily channeled; the other resists erosion more effectively. After a few seasons, however, the surface horizon weathers and covers the blue till formerly exposed.

As explained above, the direction of this valley is more nearly accordant with the direction of ice-movement; the older drift here was exposed, therefore, to more vigorous erosion. The portion of this old drift which has survived ice-erosion is the lower, unweathered parts. Thus the old drift is commonly fresher than the new.

The North Crosby exposure.—On the opposite shore of the lake, a few rods up the hill from the North Crosby Landing, a recent stream course discloses a hard bluish till, which shows no evidence of structure, overlain by Wisconsin drift. This channel in places is 15 feet deep; the maximum showing of the basal drift is about 4½ feet where it forms the bed of the cut, but it is not constant, the Wisconsin sometimes forming the entire cross-section of the cut. The hardness of the blue till here is evident from the overhanging of the bowlders (Fig. 3), which may be two-thirds disclosed before dropping from the face of the cut. We have not seen in this material bowlders more than a foot in diameter. The sharp angle of slope which this till maintains in comparison with that of the Wisconsin above is evidence also of the compressive force to which it has been subject.

Mixed exposures.—About a mile southeast of Branchport, near the point where the old valley joins the Branchport arm of the lake, a creek trenches the recent drift, which here contains scattered masses of blue till. We noted one area at the foot of the channel wall which may be in place. The Wisconsin drift here alluded to appears to be from a lateral tongue of ice which fed into the valley, thus disturbing the older deposits.

Another area where old drift is incorporated with the new is at the end of Bluff Point (Fig. 1). Here is a quantity of débris, largely local, dragged around the slope of the bluff.

Keuka Lake Outlet exposure.—The most pronounced section of the bluish till may be seen along the outlet of the lake. A typical expo-

sure is skirted by the highway and is in sight of the New York Central Railroad at Keuka Mills. Here the superjacent Wisconsin is the thinner, measuring a little less than 18 feet, while the bluish till measures nearly 30 feet. The ease with which the former weathers is demonstrated by the low angle of slope, and by the covering of vegetation; the older drift has a steep slope and no vegetation (Fig. 4), and shows very slight evidence of structure.

The outlet of Keuka Lake drops 265 feet in its course of scarcely 7 miles to Seneca Lake; it consists of a rock-bound gorge alternating with amphitheater expansions, in which one or both of the rock walls are absent where the present course crosses or enters a former more mature valley. The older drift is noted particularly in these amphitheaters of the present channel. It is probable, therefore, that the Keuka basin was tributary to the Seneca basin long before the period of bluish-till glaciation.

This same relationship of drifts is noted in the erosion channels of streams tributary to the Keuka Lake Outlet. Along the lateral from the south coming in at Milo Mills, the older drift, where not very coarse, shows a tendency to lamination, the result apparently of excessive pressure. We have noted the same condition in other localities of this region.

The most persistent expression of this bluish drift is found in the Keuka Outlet valley, which is transverse to the direction of ice-movement. The valley is very mature. Naturally the Wisconsin ice-sheet did less corrasive work here than in the arms of Keuka Lake.

Erosion and color.—Furthermore, the line of contact of the two drifts in the exposure about Dunning's and about North Crosby gives a suggestion as to the manner and amount of the erosion. The former contact is about 65 feet above lake-level; the latter, about 90 feet. In east-west cross-section the contact line is a series of sags and swells, or anticlines and synclines, presumably parallel to the direction of ice-progress, indicating its tendency to groove or plow the subjacent surface.

The color of this old drift is strikingly blue in contrast with the adjacent yellowish Wisconsin deposits, and the color persists even in the detached masses that are seen in exposures of the recent drift. It apparently is not the result of post-Wisconsin alteration; the till

has been too much protected for that, and its compactness argues against infiltering waters as the agent. The bluishness covers the bowlders and is constant in the matrix. Evidently the color antedates its erosion and burial by Wisconsin ice.

AGE OF THIS DRIFT

The evidence presented in this paper does not warrant an opinion as to the particular pre-Wisconsin epoch of glaciation with which this drift correlates. Critical study should be given a wider area southward to the outermost moraine of the Wisconsin drift; the numerous exposures noted in the limited territory already examined suggests that other superposed sections nearer the margin may show the older drift in a weathered condition.

The freshness of the subjacent bluish till about Keuka Lake does not suggest its correlation with the highly weathered till in New Jersey described by Salisbury. Nevertheless, this feature does not preclude identity of epochs, since the latter drift, which was never covered by a later till-sheet, has been subject to agents of disintegration during a period that has sufficed for the development of a well-advanced drainage system, the major streams having attained "levels more than 100 feet below the levels of the lowest summits on which the drift occurs."[1]

SUMMARY

This old drift, where now exposed, with one doubtful exception, is fresh in appearance; is very compact in structure, sometimes foliated; its bowlders preserve striae; its upper surface shows erosion, presumably somewhat beyond the removal of the weathered horizon which may be the source of some of the rather rotten crystallines now mingled with the recent drift.[2]

[1] R. D. Salisbury, *loc cit*, p. 759.

[2] The writer has just noted Gilbert's paper, "Bowlder-Pavement at Wilson, N. Y." (this *Journal*, Vol. VI [1898], pp. 771–75). The pertinent feature of this paper is the recognition of the possibility of two till-sheets, and of the certainty of "an epoch of local till-erosion by a glacier. The epoch may be a mere episode interrupting a period of till deposition by the same glacier, or it may be a part of a stage of readvance following a long interglacial period" (p. 774).

THE GLENEYRIE FORMATION AND ITS BEARING ON THE AGE OF THE FOUNTAIN FORMATION IN THE MANITOU REGION, COLORADO

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The Paleozoic section to the east of Pike's Peak, Colorado, in the Manitou region is composed of four members, as follows: (1) a basal Cambrian sandstone; (2) a limestone series, the lower half of which is Ordovician (the age of the upper half is still in doubt); (3) a fossil-bearing sandstone of Pennsylvanian age; and (4) the Fountain formation, arkose sandstones, grits and conglomerates, the lower members of which are almost certainly of Pennsylvanian age, while the upper members may in the end be definitely correlated with the Permian and Triassic. The purpose of the writer in the present paper is to describe the sandstone member, (3) in the series as given above. It has not previously been described. It contains the only identifiable plant remains of Pennsylvanian age which have been found thus far in the Rocky Mountain region. These fossils make possible its safe correlation with the Upper Carboniferous of the East. The Fountain beds appearing in the section next above cannot, therefore, be older than the Pennsylvanian, and the occurrence in them of brachiopods which have been recently found points to their being of Pennsylvanian age.

Our knowledge of the Paleozoic section in the Manitou region warrants us in making the following statement with a large measure of confidence as to its correctness. Overlying the basal granite, which with its included schist and gneiss represents the Archean and Algonkian, there are found 50 feet of upper Cambrian sandstones. The lowest member of the Cambrian is an 11-foot band of white, fine-grained quartz feldspar sandstone. The succeeding layers going upward are stained by iron a deep red-brown, and they show irregular green markings due to the presence of glauconite. It is the upper Cambrian which is represented. The amount of lime increases

as one goes up in the series, until after 50 feet have been passed a gradual transition brings in thinly bedded limestones of Ordovician age, known as the Manitou formation. The line of demarkation between the Cambrian and the Ordovician in Manitou or Williams Canyon may be drawn at the "Narrows" just below the 18-inch band of hard, red, porous limestone which contains *Dalmanella testudinaria*. The beds up to this point are lithologically similar to the sandstones and limestones at the base of the section to the north along Deadman's Creek described by W. T. Lee,[1] and the correlation is justified by a comparison of the brachiopod faunas of the two regions. Near Canyon City, Colo., where cherty layers of the Manitou limestone rest directly on the granite, the Cambrian is wanting.

Above the Cambrian in the Manitou or Williams Canyon section 266 feet of limestones (including the Ordovician or Manitou limestones) were measured. A marked unconformity appears at the top of the series. The limestones at the base of the Ordovician are thinly bedded. Higher up the single layers are each one or more feet in thickness. Many of them carry chert inclusions. The prevailing colors are gray, bluish gray, and buff. A few layers near the top show deep red. The limestones are rarely free from magnesia, but a heavy band near the top is nearly pure lime carbonate.

The Silurian and Devonian are not known in the section, nor anywhere along the Front Range in Colorado. The Harding sandstone and the Fremont limestone of Ordovician age, so well represented near Canyon City, are not found in the Manitou region. To the north along Glen Eyrie Creek, three miles from Manitou, the limestone series is 311 feet thick.[2] Here Carboniferous fossils have been obtained from the upper beds by Dr. A. W. Grabau. It seems probable that at this point the equivalent of the Millsap, as suggested by Dr. G. H. Girty, is present, although the rock is not lithologically similar to the Millsap of the type locality in Garden Park, described by Dr. Whitman Cross. In the Manitou Canyon section there is no sign of an unconformity to mark Silurian and Devonian time until the top is reached. Fossils of Ordovician age occur at

[1] *American Geologist*, Vol. XXIX (1902), p. 96.

[2] See reference to Peale's section in *Professional Paper 16*, U. S. Geological Survey, p. 153.

many points in the lower 118 feet, but the upper 148 feet are not fossiliferous. It may well be that the Millsap has no equivalent in the section at this point.

Resting on the limestone, and separated from it by an erosional unconformity, are 40 feet of gray and buff, finely laminated sandstones, made up almost entirely of quartz grains, with thin bands of black shale near the bottom of the series. This formation is below the unconformity at the base of the Fountain. Typical exposures are met along the stream-bed in Quarry Canyon, a mile to the northeast of Manitou, where the upper contact with the Fountain is exposed. The basal contact with the highest brecciated limestones of the Manitou Canyon section may be seen on the right hand just at the entrance to Manitou Canyon. Small fragments of the limestone occur in the lowest beds of the sandstone, which rest on an uneven limestone floor. Southward from this point the formation is covered by overlap of the Fountain. It may be traced northward as far as Glen Eyrie Creek, where it is well exposed, although the Fountain comes down to the basal granite a short distance beyond, to the north. The sandstone formation in question is therefore of no great thickness, and its outcrop, an eighth of a mile or less in width and but three miles long, is of small extent. It possesses considerable interest, however, because of the fossil plants which are found in the shaly layers irregularly distributed through it. A collection of these fossils was made and forwarded to Dr. David White, of the United States Geological Survey. *Lepidodendron obovatum* and *Lepidodendron aculeatum* were identified by him. Dr. White has pointed out to the writer that these species indicate a horizon equivalent to the Pottsville of Pennsylvania. These plant remains are the only ones of Pennsylvanian age recorded up to the present time from the Rocky Mountain region. The shales which contain them are bands four feet and less in thickness, black from contained carbonaceous matter and traces of coal. They occur near the base of the formation, are at times lens-shaped, and quickly thin away. They indicate swamp conditions near the level of the sea. Lepidodendron markings have also been found in the sandstones. Concretionary markings are common in certain layers. The formation has not up to the present time received a name. It is proposed to call it the Gleneyrie

formation, making use of the name of the locality in which the best exposures are met. The Gleneyrie sandstone is a strong rock to resist weathering, and the weaker overlying Fountain grits have been stripped back down the dip for some distance from their outcropping edge.

The Fountain formation next above in the series, resting on the Gleneyrie sandstone and separated from it by an unconformity with overlap, has a thickness of over a thousand feet. The formation is made up of arkose sandstones, grits and conglomerates, red, vermilion, maroon, and occasionally white. Dr. Whitman Cross, who first used the name in the Pike's Peak folio, assigned the Fountain beds to the Carboniferous. It is clear that in the Manitou region, since they overlie the Gleneyrie sandstone, they are not earlier than the Pennsylvanian. Fossils from the Fountain are extremely rare, and only two genera, brachiopods, have been found in the Manitou region. They occur 200 feet above the base of the formation in a three-foot layer of red, fine-grained, shaly sandstone. Good exposures are met above the stone house in Quarry Canyon. Here shells of Orbiculoidea are not hard to find. Dr. G. H. Girty has kindly examined the specimens and referred them tentatively to *Orbiculoidea manhattanensis*. With them a single productoid shell, resembling *Marginifera ingrata*, has been collected, but the specimen is not sufficiently good for accurate determination. *Orbiculoidea Manhattanensis* has a wider range than the Carboniferous, but its occurrence at this horizon points strongly to the Pennsylvanian age of the Fountain beds near Manitou. The "Saurian" limestone conglomerate of Triassic age, so well developed in the San Juan Mountains of southwestern Colorado, is not known along the Front Range. For the final proofs as to whether any of the upper layers of the Fountain are to be referred to the Permian or to the Triassic we must await the results of such studies as Dr. Williston has been conducting in the Canyon City field.

THE HAMILTON IN OHIO[1]

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At the beginning of the deposition of the Devonian formations belonging to the upper part of the Ulsterian and early Erian series, much of Ohio lay beneath a great inland sea. The island caused by the Cincinnati geanticline, and covering parts of Ohio, Indiana, and Kentucky, according to Ulrich and Schuchert,[2] probably became connected with the mainland to the southeast sometime during the Upper Silurian period, thus constituting it a peninsula of Appalachia. This condition probably continued until late in the Onondaga age, when the Cincinnati area once more became an island.

The Cincinnati peninsula may have extended as far north as the mouth of the Detroit River, the northern limit of the Silurian outcrop; but in this there is an element of uncertainty, since preglacial and glacial erosion might have removed the Devonian formations which may have covered the northern end of this tongue of land. But whatever the extent of this island or peninsula, the sea which surrounded it, wholly or in part, was continuous over a large part of the southern peninsula of Michigan, portions of Ontario, New York, and Pennsylvania, as well as Kentucky, Tennessee, Indiana, and Illinois.

By the beginning of the Hamilton—that is, the Erian epoch—great changes had occurred. The small gulf in eastern Ohio had expanded into the Cumberland basin, the Cincinnati island was again free from the mainland, and the Traverse strait formed a means of communication between the Dakota and Mississippian seas; but the Kankakee peninsula still formed an effective barrier between this western sea and the Indiana basin of the Mississippian.[3] In

[1] A paper read before the Biological Club of the Ohio State University, February 4, 1907. The work on this subject was done while a graduate student at the university (1905–6), and during the succeeding summer; hence it contains many of the ideas and suggestions of Professor Prosser.

[2] *New York State Museum Bulletin No. 52* (1901), p. 648.

[3] Schuchert, *American Geologist*, Vol. XXXII, pp. 143–62, and Plates XX, XXI.

other words, a great period of sea encroachment had set in which affected mainly the northwestern coast of Appalachia and the land area beyond the Indiana basin. Ohio therefore lay beneath the same sea, much enlarged since the earlier Devonian, as that covering the southern portion of New York in Hamilton time, and naturally contains deposits contemporaneous with those of New York.

As at present defined, the Devonian system in Ohio comprises the following formations:[1]

4. Ohio shale { *c*) Cleveland shale; *b*) Chagrin formation; *a*) Huron shale
3. Olentangy shale
2. Delaware limestone
1. Columbus limestone

The Columbus limestone is the southern extension of the Dundee of Michigan and the eastern extension of the Jeffersonville of Indiana and Kentucky. This equivalence is shown, not only by lithological similarity and stratigraphic identity, but conclusively by the faunal unity. These Indiana, Michigan, and Ohio limestones are but the local representatives of the Onondaga of New York, or, if we accept the conclusion of Ulrich and Schuchert,[2] which is also supported by Dr. J. M. Clarke,[3] that the Onondaga fauna invaded the state from the west, perhaps it is better to say that the Onondaga limestone is but the New York representative of these limestones.

But what of the Delaware limestone? Newberry and Orton included it with the Columbus as the Ohio equivalent of the "Corniferous" (Onondaga).[4] This, however, seems to have resulted mainly from a mistaken correlation of the deposits occurring in the eastern part of Sandusky,[5] where the upper layers of the Columbus limestone show some variation, both lithological and faunal, from that of the vicinity of the city of Columbus, and approach somewhat the appearance of the true Delaware. Professor Winchell, however,

[1] Prosser, *Report of the Geological Survey of Ohio*, Fourth Series, Bulletin No. 7, p. 3.

[2] *Loc. cit.*, pp. 652, 653, 663.

[3] *Ibid.*, pp. 667, 668.

[4] *Report of the Geological Survey of Ohio*, Vol. I, Part 1, pp. 144, 150, 151; Vol. II, Part 1, pp. 190–92, also 290, 3d note; Vol. III, p. 606.

[5] Prosser, *Journal of Geology*, Vol. XIII, No. 5 (1905), pp. 439–42.

having made an extensive study of these outcrops over the state, pronounced them of Hamilton age.[1] Dr. Newberry agreed that the Olentangy shale, or at least the deposit immediately overlying his "Corniferous" in the northern part of this state, may be Hamilton,[2] and this was evidently supported by the fauna of the Prout limestone, a thin fossiliferous layer occurring immediately below the Huron shale in northern Ohio, but he strenuously objected to the correlation of the Delaware with the Hamilton of the east.[3]

Some time later (1878) Dr. Whitfield visited central Ohio and discovered the brown shale carrying a Marcellus fauna at the base of the Delaware. This, he says, forms "a dividing line between the lower and upper Devonian, as between the limestones of the Upper Helderberg and those that properly refer to the Hamilton period."[4]

Again referring to Ulrich, Schuchert, and Clark, we find that the Marcellus shale fauna very likely entered southeastern New York from the Atlantic, and thence spread westward.[5] Deposits of unquestioned Onondaga in western New York are in all probability contemporaneous with true Marcellus deposits in the eastern part of the same state.[6] This may also be true of the upper part of the Columbus limestone, but the finding of Marcellus deposits in this vicinity (Columbus), even though meager, proves that "the invasion of the black muds which produced the Marcellus beds, and with these the diminutive fauna characteristic of these beds," reached as far west as central Ohio, and hence marks an epoch of change which cannot easily be overlooked. By the time this Marcellus invasion had reached the eastern shore of the Cincinnati island its impetus seems to have been nearly exhausted, as the brown, shaly portion of the Delaware measures but 6 feet and does not occur at all in Indiana, nor does it appear to be recognized in Michigan.

About this time the Hamilton invasion began. The species

[1] *Report of the Geological Survey of Ohio*, Vol. II, Part 1, pp. 244, 289–94, 338, 339, 426, 427, etc.

[2] *Ibid.*, pp. 189, 190.

[3] *Ibid.*, Vol. 1, Part 1, p. 144; Vol. II, Part 1, p. 290.

[4] *Proceedings of the American Association for the Advancement of Science*, Vol. XXVIII (1880), p. 298.

[5] *Loc. cit.*, pp. 665, 668.

[6] Grabau, *New York State Museum Bulletin No. 92*, p. 231.

characteristic of this fauna, Dr. Clarke tells us,[1] invaded New York from the west, part coming up through the Indiana basin and another part through the Traverse strait from the Dakota sea, but the great majority of the species were probably developed from the Onondaga fauna of the northwestern Mississippian sea. Professor Schuchert thinks that the Connecticut channel still continued to admit a few European species during the Hamilton time,[2] but Dr. Grabau says that its efficiency "was greatly diminished."[3] We thus see the heterogeneous character of the Hamilton fauna, which is most marked in regions, such as Ontario and western New York, where all of these elements blended, and thus an excuse, in more isolated regions, for great variation even in true faunas of this age.

Following the base of the Delaware northward, it soon loses its shaly character, and yet even at Stratford, 20 miles north of Columbus, blocks of the massive blue layers from this horizon split into thin, somewhat shaly fragments after extensive weathering, and still contain the same fauna characteristic of these beds in Franklin County. Above the 6-foot shaly zone occur 30 feet of blue limestones, varying from thin-bedded to massive, and sometimes, as at Delaware and Owen, having bands of soft, blue shale from a few inches to a foot in thickness, at different horizons. In Franklin County the formation contains much black chert, which usually occurs as layers alternating with limestone, or sometimes taking the nature of zones; but northward the amount of this material decreases, until at Sandusky little or none occurs. In studying this formation and its fauna, it appears to me that this physical feature has been an influential factor in classifying this deposit among the "Corniferous" rocks. There is little in the lithological appearance of this formation, it is true, which suggests the soft, blue shales of the Eighteen Mile Creek outcrops, except perhaps its persistent blue color; but, on the other hand, the Hamilton deposits of Indiana and Michigan are mainly limestones. It appears, then, that the distinction must rest on the faunal evidence which may be extracted from the various outcrops.

The important outcrops of this formation follow the eastern and

[1] *New York State Museum Bulletin No. 52*, p. 669.

[2] Schuchert, *American Geologist*, Vol. XXXII, p. 162.

[3] Grabau, *New York Museum Bulletin No. 92*, p. 233.

northwestern shores of the Cincinnati island. Taking up first the eastern shore, some forty outcrops of the Columbus have been visited and from these a total of nearly 175 distinct species have been collected, and many more reported by other collectors. The Columbus sea, in other words, was a veritable aquarium in which flourished one of the richest faunas that geological history records. Twenty-five sections, in which the Delaware limestone outcrops, have been examined, and from these a fauna of 71 species has been obtained. Among these we find the following relation: 25 Hamilton species; 16 "Corniferous"-Hamilton species; 13 "Corniferous" species, of which perhaps 3 were originally described from the Delaware and at least do not occur in the Columbus limestone; 17 species (mainly *Corals* and *Bryozoa*) unidentified. Among the Hamilton species are such as, *Lingula ligea* Hall, *Camarotœchia prolifica* Hall, *Ambocœlia umbonata* (Conrad), *Camrotœchia sappho* Hall, *Spirifer audaculus macronotus* Hall, *Chonetes scitulus* Hall, *Glyptodesma erectum* Conrad, *Nyassa arguta* Hall, *Grammysia bisulcata* (Conrad), *Sphenotus cuneatus* (Conrad)—a collection of species which is hard to bring into the "Corniferous" (Onondaga) category.

In northwestern Ohio the evidence is even stronger. Here the rocks rise very little above drainage level, hence a good section is hard to obtain, but along Ten Mile Creek and Auglaize River, at opposite ends of the line of outcrop, fair sections may be found. These two agree in all essentials, both lithologically and paleontologically. Of the 27 feet, all quite fossiliferous, exposed along Ten Mile Creek, the lower 6 feet are soft, blue shales or shaly limestones, followed by 11 feet of soft and compact, blue to drab limestone, with a considerable amount of white chert, and capped by 10 feet of massive, compact, drab limestone. This section compares favorably with that of the Traverse of Michigan; in fact, it is but a continuation of the outcrops of that formation in Monroe County.

Fifty-nine species were collected from this locality and range as follows: 33 Hamilton species; 10 "Corniferous"-Hamilton species; 6 "Corniferous" species; 10 species unindentified. Among the fossils from this section are the following characteristic Hamilton species: *Favosites hamiltoniae* Hall, *Favosites nitella* Winchell, *Heliophyllum halli* Edwards and Haime, *Strombodes alpenensis* Rominger,

Chonetes scitulus Hall, *Spirifer pennatus* (Atwater), *Leiorhynchus laura* (Billings), *Pleurotomaria sulcomarginata* (Conrad), *Tentaculites bellulus* Hall, *Phacops rana* (Green).

No argument is sufficiently strong to place such a collection of species on the Onondaga list. It is, in fact, a true Hamilton fauna.

How much of southeastern Ohio may contain Marcellus deposits, or to what extent, we do not know, but it is certain that the eastern shore of the Cincinnati island felt the effects of the changed conditions which this invasion brought about, while Franklin and Delaware Counties have recorded a trace of the black muds which these swampy seas have left. The impoverished and diminutive fauna which we find in the base of the Delaware proves that the luxuriant life which flourished during the Columbus stage was all but blotted out, and when more favorable conditions were restored, approaching, although never reaching, those which had previously existed, it was not the same fauna that took possession, but one composed of the few surviving Columbus species and a new lot probably wandering south from the hoards which were invading New York at this time. On the northwest coast of the island, however, conditions were different. It is probable that the Marcellus invasion never reached this point, but that the change from the Columbus to the Delaware fauna was gradual. Unfortunately the outcrops visited did not show the contact of these two formations, but the upper part of the Columbus in the sections of that part of the state shows evidence of a marked change in the fauna, which, by the time the shale-forming conditions of the Ten Mile Creek section had set in, had reached a complete conversion into that of the Traverse-Hamilton. To a certain extent the same is true at Sandusky, where these changes in progress in the upper part of the Columbus misled even Dr. Newberry and caused him to call it Delaware. The difference between the Delaware outcrops in the northwestern and central parts of the state may be accounted for in part by supposing, what seems to have been the case, that a spur or peninsula from the Cincinnati island extended as far northward, perhaps, as the present Canadian shore of Lake Erie, thus forming a more or less effective barrier against the fauna which was crowding eastward, and that in this somewhat protected central part of the state the Hamilton invasion was less intense, and thus

the few remaining "Corniferous" species were better able to survive.

Gathering all of the available evidence, there seems to be no substantial support for any other conclusion than that the base of the Delaware marks the beginning of the Hamilton period in Ohio.

Whether the Olentangy shale also belongs to the Hamilton or Erian period, or how much of the deposits above the Delaware limestone belong to that age, is beyond the intentions of this paper. There are some reasons for believing that this shale should rather be classed with the succeeding formation, since other bands of a very similar if not identical, lithological nature occur within what is considered the Ohio shale. It seems certain, however, that Dr. Newberry's Prout Station section is Hamilton.[1] If this be the northern equivalent of the Olentangy shale, as is very generally supposed, there can be no further question as to its age, and the total thickness of the Hamilton in central Ohio is then at least 60 feet.

In the northwestern part of the state the Olentangy shale is apparently wanting, so that the limestones and shales (Traverse) succeeding the Columbus limestone probably represent both the Delaware limestone and the Olentangy shale in that section. The relations existing between these deposits in Ohio, Michigan, and New York may then be stated somewhat as follows:

Michigan	Ohio	New York
Traverse group	Olentangy shale Delaware limestone	Hamilton beds Marcellus shale
Dundee limestone	Columbus limestone	Onondaga limestone

[1] *Report of the Geological Survey of Ohio*, Vol. II, Part I, p. 188.

Reviews

Reports on Geological Investigation. By BAILEY WILLIS. Includes: "Geological Exploration in Eastern China," "Studies in Europe," "Geological Research in Continental Histories," and "Artesian Water Conditions at Pekin, China." Washington, D. C. Extract from the *Fourth Year Book* of the Carnegie Institution of Washington, 1906. Pp. 192–220.

This paper gives the preliminary results of the author's duties, and his plans for extensive investigation in the future. In Europe he recognizes two general types of mountains: "(*a*) The mountains of central Germany and northern Austria, which were folded at the close of the Paleozoic, were eroded to a peneplain during the Cretaceous, and have since passed through a complex history of warping and erosion; and (*b*) mountains of the Karpathian type, which were folded during the Tertiary, were subsequently eroded to a surface of mature topography, still retaining marked relief, and have since been strongly warped, in some cases before the close of the Tertiary, in others during Quaternary time." The Appalachians belong in class (*a*), the Himalaya probably in class (*b*).

The systematic gathering and publication of existing data on continental histories will be a great boon to science. The problems outlined seem to be largely those set forth in the recent work on geology by Chamberlin and Salisbury. Willis' conclusions, and the development or alteration he may make in the theories of these authors, will be eagerly awaited by all delvers in philosophical geology. C. W. W.

The Geology of Southern Rhodesia. By F. P. MENNELL, Rhodesia Museum, Bulawayo. Special Report No. 2. Bulawayo, 1904. Pp. 42; 11 figs. and geological map.

This report embraces Mashonaland and Matabeleland, or that part of the Chartered Company's territory which is south of the Zambesi River. The geology is, in many respects, similar to that of the interior of North America.

The Archean consists of schists and gneiss derived from both sedimentary and igneous material. The great granitic masses occupying nearly one-third of the territory and formerly regarded as part of the Archean are shown to be intrusive batholiths.

The Archean is succeeded by what the author calls the Eparchean,[1] which he says may be called also the

Banded Ironstone Series, from the usual name of their principal member. The characteristic feature of these beds is the peculiar banded, flinty rock, which appears under the microscope to be in all probability an altered, fine-grained, mechanical sediment silicified and highly charged with ferruginous material, arranged in parallel bands. They alternate with sheared conglomeratic and arenaceous beds, slates (phyllites), and gneissic bands, which may result either from the crushing of acid intrusives or of tuffs. These beds are usually almost vertical. . . . .

Any American geologist will notice the resemblance of this series to the Algonkian or Proterozoic. The term Eparchean is inadmissible since Lawson has used it for the erosion interval at the base of the Algonkian.[2]

The presence in Rhodesia of Paleozoic below the Permian is doubtful. The latter is a flat coal-bearing, non-marine series of sandstone, shale, conglomerate, and occasional limestone. The coal promises to be of economic importance. Mesozoic strata are absent.

The Tertiary ("Forest Sandstone") consists of red and white sandstone, with occasional conglomeratic or gravelly beds, bands of shale, or impure limestone, and great quantities of interbedded basaltic lava. The author believes that the sedimentary beds are in large part the result of aggradation in an arid climate. Though he constantly refers to them as lacustrine, his description would accord well with a subaerial origin. The description and photograph (Fig. 8) of the "schist country on the plateau" are strongly suggestive of a peneplain, though it is not described as such.

C. W. W.

Recent Changes in Level in Yakutat Bay Region, Alaska. By RALPH S. TARR AND LAWRENCE MARTIN. (Bulletin of the Geological Society of America, Vol. XVII, pp. 29–64, 1906.) Pls. 12–23.

Recent Changes of Level in Alaska. Reprint from *The Geographical Journal*, July, 1906, pp. 30–43.

No proof of recent shore elevation could be more complete and convincing than that presented by the authors in these papers. Their physiographic evidences are: elevated rock benches, elevated sea caves and

[1] In the Correlation Table (p. 24) this is included in the Archean, though separated in the text (p. 11).

[2] Andrew C. Lawson, "The Eparchean Internal: A Criticism of the Use of the Term Algonkian," *University of California, Bull. Dept. Geology*, Vol. 3, No. 3. Berkeley, Cal., 1902.

chasms, elevated beaches, elevated alluvial fans or deltas, till shore-lines, new reefs and islands, and reclaimed land. The biological evidences are: elevated barnacles, mussels, bryozoans, and other marine organisms, still fresh, with the attached forms clinging to the rocks; also the mingling of land and sea life, parallel lines of stranded driftwood, and destruction of life. There is even human evidence of the uplift: two careful students of old shore-lines, Russell and Gilbert, examined the shores of the bay on parts of the coast where uplifted shore-lines are clearly preserved, the former geologist in 1890 and 1891, the latter in 1899, but three months before the earthquake, yet neither observed any evidence of elevation; the ship of the Harriman expedition, which carried Gilbert, sailed close by the uncharted reefs produced during the earthquake, but the sailing master did not see them; natives on various parts of the bay were disturbed by the earthquake and waves; and they observed many of the phenomena of elevation. In 1905 the authors found alders, not over 4 years old, growing in the rock crevices among barnacles 17 feet above high tide. This array of evidence seems to leave no doubt that changes in level were produced during the earthquakes of September, 1899.

The change of level with reference to the sea was considerable, reaching a maximum of 47 feet, 4 inches. This diastrophism is clearly normal faulting of block type, many of the faults having been observed in the field. With reference to sea-level, one block was depressed; the largest block, about 25 miles long, was raised with differential elevation; the others were not tilted, so far as observed.

It is interesting to note that this contribution by Messrs. Tarr and Martin has a pertinent bearing on the Suess theory of general downward movement in normal faulting, in that they have shown (1) that during earthquakes in September, 1899, fault blocks were separately and differentially elevated, with reference to sea-level; and (2) no withdrawal of the sea from other parts of the coast was observed at that time.

C. W. W.

Notes sur la tectonique de la platforme cristalline de la Russie méridionale. (Text in Russian, summary in French.) By W. LASKAREW. Separate from Tome XXIV, *Bulletins du comité géologique*, No. 110. St. Petersburg, 1905.

The region described is a dissected platform of paleozoic and older rocks extending from the Sea of Azov to the Carpathian Mountains. The platform is practically a great horst bounded on all sides by faults. The Podolian horst described by Suess lies on its northwest border. The faults

are mostly repeated normal faults, and vary in age from Carboniferous (post-Devonian) to Oligocene, with most of the movement probably before the Jurassic.

Novel features of the paper are: (1) The relation of the platform to the distribution of gravity (pp. 242–46). A line of deficiency in weight has been traced by J. Collet close to the eastern margin of the platform. (2) The relation of the structure of the platform to the magnetic phenomena (pp. 246–49). At the southern edge of the platform, P. Passalsky observed coincidence between magnetic anomalies and the position of folds, as well as the magnetic character of the rocks. The author ascribes the lack of such coincidence at the northern margin to extensive faulting. (3) The relation of the platform to earthquakes (pp. 249–52). Earthquakes have minimum frequency—about $\frac{4}{1}$ per cent. This low frequency is assigned to cessation of deformation within the region, and to the great number of repeated boundary faults which protect the platform from foreign shocks.

C. W. W.

Geography and Geology of Alaska. By ALFRED H. BROOKS, with a Section on "Climate" by CLEVELAND ABBE, JR., and a topographic map and description thereof by R. U. GOODE. (U. S. Geological Survey, Professional Paper No. 45.) Pp. 327, 32 plates. Washington, D. C., 1906.

The main features of the geography of Alaska are classified and discussed in some detail. Four geographic provinces are recognized: (1) the Pacific Mountain system; (2) the Central Plateau; (3) the Rocky Mountain system, and (4) the Arctic Slope. There are maps showing the position of mountain axes, geology, glaciation, and a large topographic map on a scale of 40 miles to the inch. The term "basin lowlands" is introduced (p. 281, and Fig. 5) for "broad, flat depressions, separated from the encircling highlands by almost unbroken scarps." "One of the characteristic features of this lowland type is that within it the water courses are sluggish and aggradation is going on, while the comparatively narrow channels of exit are being rapidly cut down." All the extensive peneplains of Alaska (Coast Range, Chugach, Yukon, Endicott, and Anaktuvuk) are thought to have been formed during post-Kenai (i. e., post-Eocene) and pre-Pliocene times. The present great difference in elevation of these peneplains is assigned to Pliocene and later deformation. There are a few smaller, less extensive base-levels of Pliocene or more recent date.

C. W. W.

Reconnaisance of Some Gold and Tin Deposits of the Southern Appalachians. By L. C. GRATON; with notes on the Dahlonega Mines, by WALDEMAR LINDGREN. (U. S. Geological Survey, Bulletin No. 293.) Pp. 134, 9 plates. Washington, D. C., 1906.

The tin-ore occurs in ore-shoots of slight lateral extent. The only tin-mineral present is Cassiterite which is regarded as a primary constituent of the pegmatite in which it is found. Most of the production is from the Ross mine, near Gaffney, S. C., which in 1903 produced 35,925 pounds of concentrates, and in 1904, 74,396 pounds, which would average probably 66 per cent. to 70 per cent. tin.

The earliest gold-mining in the United States was probably in this region, but the production is not recorded until 1829, when $3,500 was obtained from placers in Lancaster and Chesterfield Counties, S. C. The total production of the Southern Appalachians has probably been about $10,000,000. In general placer-mining has been profitable, lode-mining unprofitable.

The ore is low grade, averaging $8–$12 gold per ton. Fissure veins of pyritiferous quartz are common. They are notably irregular and non-persistent. The most interesting and productive ores are replacement deposits which occur "in volcanic rocks of the quartz-monzonite-porphyry group, and are most common in the fragmental varieties or tuffs." These deposits are large lenticular bodies of silicious, pyritiferous ore, "forty or fifty to hundreds of feet in length and twenty to several hundred feet in width." Many of them do not extend one hundred feet below the surface, others go down as far as present workings, or several hundred feet. The distribution of the ore-values is suggestive of secondary enrichment by descending solutions. C. W. W.

Geology and Paleontology of the Judith River Beds. By T. W. STANTON AND J. B. HATCHER. With a chapter on "The Fossil Plants," by F. H. KNOWLTON. (U. S. Geological Survey, Bulletin No. 257.) Pp. 174, 19 plates. Washington, D. C., 1905.

The Judith River beds are non-marine Upper Cretaceous sandstones, shales, and clays, with lignite occurring in northern and central Montana and adjacent areas of Canada. The authors have established the fact that the Judith River beds belong to the Montana division, that they are separated from the Laramie above by several hundred feet of shales (Bearpaw shales) with the marine fauna of the Pierre, that they are underlain by marine shales and sandstones which constitute a distinct horizon (Claggett

formation) in the Montana group, and that they are strictly equivalent to the Belly River beds of Canada. The authors believe that the Eagle formation marks the base of the Montana group, that the Bearpaw shales, Judith River beds, Claggett, and Eagle formations belong to the Montana group and are "equivalent to the Pierre as that term is generally understood," and that "the use of the term Fox Hills as a formation or horizon name outside of the original area in South Dakota is of doubtful propriety."

C. W. W.

The Limeless Ocean of Pre-Cambrian Time. By REGINALD A. DALY. (Reprint from *American Journal of Science*, Vol. XXIII, February, 1907, pp. 93–115.)

The concertion of limeless ocean is urged as an explanation of the absence of fossils in non-metamorphic pre-Cambrian rocks. In Eozoic time the lime-salts inherited form Azoic time were precipitated as carbonate, because of the production of ammonium carbonate by decomposing organic matter. This and other conclusions are based on premises some of which are observational and sound, but others are postulates and deductions of indeterminate value. Perhaps unintentionally the author (p. 113, premises 9, 10, 11, and p. 100) has left the impression that the $CaCO_3$ of the sea has been always derived mainly from pre-existing limestone, instead of from decomposed silicates. From the hypothesis interesting deductions are made as to the early development of the hard parts of organisms.

C. W. W.

Rate of Recession of Niagara Falls. By G. K. GILBERT. Accompanied by a Report on the Survey of the Crest. By W. CARVEL HALL. (U. S. Geological Survey, Bulletin No. 306.) Pp. 31, 11 plates. Washington, 1907.

"The rate of recession of the Horseshoe Fall, or the rate of lengthening of the Niagara gorge, during the sixty-three years from 1842 to 1905 is found to be 5 feet per annum, with an uncertainty of 1 foot. For the thirty-three years from 1842 to 1875 the rate was apparently slower than for the thirty years from 1875 to 1905. The rate of recession of the American Fall during the seventy-eight years from 1827 to 1905 was less than 3 inches per annum." The latter figure is of interest to geologists because somewhat representative of the river's activity in gorge-making when the volume of water was much less."

C. W. W.

Geology of the Lower Colorado River. By WILLIS T. LEE. (Bulletin of the Geological Society of America, Vol. XVII [June 23, 1906]. Pp. 275–84, plates 32–24.)

In this interesting paper the origin of the Grand Canyon is placed at the very close of the Tertiary and most of its erosion is assigned to the early Quaternary. During the Pliocene and early Quaternary the Lower Colorado flowed through a broad valley occupied by Virgin River at the north and extending southward 125 miles to the mouth of Williams river. It was deflected from this course by detrital aggradation and lava flows which filled a part of the old valley to a depth of 800 feet. Since then it has lowered its new channel over 2,000 feet and cut Boulder, Black, Needles, and Aubrey canyons. The canyon has since been filled with gravel to a depth of 700 feet, and later re-excavated below its present bottom. At present aggradation is in progress. C. W. W.

Geology and Mineral Resources of Part of the Cumberland Gap Coal Field, Kentucky. By GEORGE HALL ASHLEY AND LEONIDAS CHALMERS GLENN. (U. S. Geological Survey, Professional Paper No. 49.) Pp. 239, 40 plates. Washington, D. C., 1906.

The rocks of this field all belong to the Pottsville group, with a thickness here about 4,000 feet. The lower third of the rocks are mainly sandstones, while the upper two-thirds, carrying the coal beds, are about equally sandstone and shale. The structure is that of a flat-bottomed U-shaped trough; dips do not average more than 100 feet to the mile. There are thirteen workable coals. Eight are mined; thickness, 4 to 6 feet. The output is from 600,000 to 1,000,000 tons a year, used mainly by the L. & N., and the Southern Railways and by a blast furnace at Middlesboro.

C. W. W.

Trent River System and Saint Lawrence Outlet. By ALFRED W. G. WILSON. Rochester, N. Y., 1904. (Bulletin of the Geological Society of America, Vol. XV, pp. 211–42, Plates 5–10.)

The configuration of the Trent River system of eastern Ontario is determined by joints in the Ordovician limestone of that area. Farther north in the Archean, pre-Ordovician faults influence the drainage. Neither glacial erosion nor deposition have been sufficient to obliterate the pre-glacial drainage lineaments determined by joints. But the pre-glacial direction of drainage was prevailingly to the southwest and this has been largely changed by tilting.

The St. Lawrence outlet is a complex of three partly submerged valleys. The straits between the islands mark sags in the inter-basin ridges. The former drainage of the locality was southwestward across the basin of Lake Ontario, in the edge of which many of the pre-glacial channels may be detected by sounding. C. W. W.

Moulin Work Under Glaciers. By G. K. GILBERT. (Bulletin of the Geological Society of America, Vol. XVII, pp. 317–20, plates 40–42.)

Describes, figures, and explains the formation of some interesting examples of complete and incomplete glacial pot-holes.

C. W. W.

Gravitational Assemblage in Granite. By G. K. GILBERT. 1906. (Bulletin of the Geological Society of America, Vol. XVII, pp. 321–28, Plates 43–46.)

The author suggests that gravity may have caused some aggregations of feldspar, and of hornblende, in certain granitic rocks of the Sierra Nevada. The only evidence offered is the observation that these aggregates of phenocrysts are of materials, lighter in one case, heavier in the other, than the rest of the rock; and that there is little granitic material between the phenocrysts.

Some banding observed in the granite is assigned provisionally to deposition under gravitational control. An "unconformity" in this granite is described and photographed (p. 324, Fig. 1, and Plate 44). This is thought to be due possibly to internal magmatic deposition and erosion.

C. W. W.

Post Pleistocene Drainage Modifications in the Black Hills and Bighorn Mountains. By GEORGE ROGERS MANSFIELD. Cambridge, Mass., 1906. (Bulletin of the Museum of Comparative Zoölogy, Vol. XLIX; Geological Series, Vol. VIII, No. 3, pp. 59–87.)

Extensive high deposits of Pleistocene river gravels are described in both districts. The former general courses of the streams that deposited these gravels is determined by an ingenious plot (Plate I) on which each gravel locality is connected with the possible sources of its pebbles. The modification of the Pleistocene stream courses through adjustment, capture, and crustal warping is discussed. The entrenchment of the streams in post-Pleistocene time is assigned "to uplift or broad up-warping, rather than to climatic oscillation." C. W. W.

The Origin and Structure of the Roxbury Conglomerate. By GEORGE ROGERS MANSFIELD. Cambridge, Mass., 1906. (Bulletin of the Museum of Comparative Zoölogy, Vol. XLIX; Geological Series, Vol. VIII, No. 4, pp. 92–271.)

The Roxbury Conglomerate is a series of sediments 5,000 to 12,000 feet thick in and adjacent to the Boston Basin, composed largely of coarse conglomerate, with some sandstone and shale. It is probaply of Carboniferous age.

After a careful analysis of the evidence "largely negative and unsatistory," the author favors a hypothesis of non-marine origin. "Glaciers were not directly concerned with the deposition of the conglomerate, but they probably furnished material to the torrents, by which it was deposited." High grades and mountainous condition prevailed about the area of deposition.

A useful part of the paper is an analytical discussion (45 pages) of the origin of conglomerates in which the known kinds of evidence are classified, described, and weighed. C. W. W.

Paleontology of the Malone Jurassic Formation of Texas. By FRANCIS WHITTEMORE CRAGIN. Washington, D. C., 1905. (U. S. Geological Survey, Bulletin No. 266.) Pp. 109, 29 plates.

In western Texas at Malone Mountain, there are deformed upper Jurassic strata of gypsum, conglomerate, limestone, and shale. The marine fauna is rich and practically identical with that of a number of Mexican localities that lie in line with the Malone occurrence. Many new species are described and figured, including some ammonites that are unfortunately without figures of septa. Cephalopods are not abundant, but the few forms present are decisively upper Jurassic.

The reviewer takes interest in noting that this fauna contains elements, related if not ancestral, to elements in the Pacific Coast Upper Cretaceous, and other elements that have relatives in the succeeding Lower Cretaceous beds of Texas. C. W. W.

Recent Cave Explorations in California. By. JOHN C. MERRIAM. Reprint from *American Anthropologist* (N. S.), Vol. VIII, No. 2, April-June 1906, pp. 221–28.

Dr. Merriam describes the fossils and deposits in four California caves. In the Potter Creek cave, which was formed at the same time as a terrace now 800 feet above the McCloud River, there is about 25 feet of fossil-

iferous stalagmite which has yielded several thousand bones and fragments, of which between 4,000 and 5,000 are determinable specimens. Fifty-two species have been determined, including twenty-one extinct species. The fauna is certainly as old as the middle Quaternary.[1] Associated with these fossils are some pointed and polished bones, fragments, and others with peculiar perforations that seem hard to explain except by human origin. The phenomena of the other caves are similar, though more recent. In one of them were parts of a human skeleton incrusted with stalagmite. But Dr. Merriam is very conservative, and casts doubt both on the human origin of the perforated and polished bones, and on the great antiquity of the human skeleton. C. W. W.

Geology of the Volcanic Area of the East Moreton and Wide Bay Districts, Queensland. By H. I. JENSON. (Proceedings of the Linnean Society of New South Wales, April, 1906, Part I, pp. 73–173, Plates V–XVI.)

The physiography, general geology, and petrology are discussed. There are pre-Devonian schist, and gneiss, probably Archean. The Paleozoic, including the Gympic series (Carboniferous?), is highly metamorphosed. The only other sedimentary rocks are faulted, Jura Trias feldspathic sandstones, with tuff and coal. The igneous rocks include tonalite, granite, aplite, epidiorite, granophyre, quartz-diorite, porphyrite, monzonite, sölusfergite, rhyolite, trachyte, comendite, and pantellerite. These are described petrographically, with chemical analyses, and calculations of their positions in the quantitative system. C. W. W.

Copper Deposits of the Clifton-Morenci District, Arizona. By WALDMAR LINDGREN. (U. S. Geological Survey, Professional Paper No. 43.) Pp. 375, 24 plates. Washington, D. C., 1905.

The three principal mines of this district produced 53,400,000 pounds of copper in 1903. The ores are associated with post-Cretaceous intrusions of acid porphyries, and are thought to have derived their metals directly from the solutions accompanying these intrusions. Most of the ore is in the form of local replacement and impregnation of the country rock through contact metamorphism; circulating atmospheric waters were not concerned in their origin. But there are also some fissure veins of the

[1] See Sinclair, "North American Archaeology and Ethnology," *Publications of the University of California*, Vol. 2, No. 1.

ordinary type. The report discusses the general geology, the ore-deposits and their minerals, with description of one new species, *Coronadite*. There is also an extended discussion of metasomatic processes, and finally a description of the mines and mineral-deposits.

C. W. W.

Slate Deposits and Slate Industry of the United States. By T. NELSON DALE. With sections by E. C. ECKEL, W. F. HILLEBRAND, and A. T. COONS. (U. S. Geological Survey, Bulletin No. 275.) Pp. 154, 25 plates. Washington, D. C.

The phenomena of slate are described and explained. The sedimentary slates are classified in two divisions: clay slates and mica slates; and the latter division, which includes all commercial slates, is subdivided into: (1) fading and (2) unfading, according to the presence or absence of sufficient $FeCO_3$ to produce discoloration on weathering. Further subdivision is into: (*a*) graphitic slate, (*b*) hematitic (reddish), (*c*) chloritic (greenish), (*d*) hematitic and chloritic (purplish). The slates of fifteen states are described. Merriam's tests for strength, toughness, density, softness, porosity, and corrodibility are given for a number of slates, and the comparative characteristics discussed. The slate production of the United States in 1903 was $6,256,885; in 1904 it was $5,617,195.

C. W. W.

A Preliminary Reconnaissance of the Mancayan-Suyoc Mineral Region, Lepanto, P. I. By A. J. EVELAND. (Bulletin No. 4, The Mining Bureau, Manila, P. I., 1905. Pp. 58, 42 plates.)

The rocks of this region consist of schists and dioritic rocks of unknown age, Eocene limestone and conglomerate, and volcanics. The ores carry both gold and copper, but are developed only in the most primitive way.

C. W. W.

The Coal Deposits of Batan Island, with Notes on the General and Economic Geology of the Adjacent Region. By WARREN D. SMITH. (Bulletin No. 5, The Mining Bureau, Manila, P. I., 1905. Pp. 56, 21 plates.)

The general region is volcanic and of recent age. Batan, however, is composed largely of folded sedimentaries ranging in age from Eocene to Pleistocene, and resting on pre-Tertiary dolerite and other rocks. There are eleven coal seams of which two are generally workable. The coal is good steam coal.

C. W. W.

Oil Fields of the Texas-Louisiana Gulf Coastal Plain. By N. M. FENNEMAN. (U. S. Geological Survey, Bulletin No. 282.) Pp. 146, 11 plates. Washington, D. C., 1906.

The oil of this region generally occurs beneath low mounds. At depths of 800 to 1,600 feet these mounds contain three substances that are not found in drill-holes away from the mounds, namely: (1) crystalline limestone, frequently dolomitic and usually porous or cavernous; the caverns are filled with oil and frequently they are lined with sulphur crystals; (2) gypsum, both the massive rock and as an admixture in sands and clays, occuring nearly always below the limestone; (3) rock salt and salt solutions impregnating sand, occuring below the gypsum. The oil is associated with the limestone and with the overlying unconsolidated sands. The position of the mounds is marked by rising ground water as indicated by the temperature and salinety of the water. It is thought that these rising waters have introduced and segregated the limestone, gypsum, and salt under the mounds. Possibly the pressure extorted during the growth and alteration of the bodies of limestone, gypsum, and salt has been sufficient to raise the mounds. C. W. W.

The Constitution of the Interior of the Earth as Revealed by Earthquakes. By R. D. OLDHAM. (Quarterly Journal of the Geological Society, Vol. LXII, 1906, pp. 456–73. London, 1906.)

The author agrees with most recent seismologists in believing that the core of the earth does not transmit tremors with the facility of the rest of the planet. He does not suggest whether this inability to transmit waves is due to a composition of iron, compressed gas, or other substance. The central core occupies about four-tenths of the diameter of the earth. "The interior of the earth after the outermost crust of heterogeneous rock is passed, consists of a uniform material, capable of transmitting wave-motion of two different types at different rates of propagation; this material undergoes no material change in physical character to a depth of six-tenths of the radius." C. W. W.

The Geological Map of Illinois. By STUART WELLER. Illinois State Geological Survey, H. Foster Bain, Director. Bulletin No. 1. Urbana: University of Illinois, 1906.

This is a provisional geological map in twelve colors, scale 12 miles to the inch. It is accompanied by 25 pages of text descriptive of the formations and structure. C. W. W.

Types of Sedimentary Overlap. By AMADEUS W. GRABAU. (Bulletin of the Geological Society of America, Vol. XVII, pp. 567–636.) Rochester, N. Y., 1906.

The two main types of progressive sedimentary overlap are the marine, in which successive beds overlap toward the source of supply, and the non-marine, in which they overlap progressively away from the source of supply. Phenomena of overlap are described in detail, and the principles deduced from them are applied to the basal Paleozoic series, the basal Mesozoic series, the Devonian Black Shale problem, Saint Peter sandstone, Dakota sandstone, the Chemung-Catskill, Pocono, Mauch Chunk, Pottsville, and other examples. The author has reached the conclusion that the Black Shale of the southern Appalachians is Mississippian.

C. W. W.

Interglacial Periods in Canada. By A. P. COLEMAN. Imprenta y fototipía de la Secretaría de Fomento, México. Callejón de Betlemitas numero 8, 1906.

In this paper, which was read before the Mexican meeting of the Geological Congress (1906), the author shows "that extensive interglacial beds of at least three ages occur in Canada, the oldest in British Columbia and Alberta; two later ones, probably between the Illinoian and Iowan, and the Iowan and Wisconsin ice ages, in southern and northern Ontario. Extensive interglacial periods have not yet been disclosed in eastern Canada, though an interesting lignite bed in Cape Breton island is probably interglacial. The most thoroughly studied interglacial formation, that of Toronto, has furnished a large flora and fauna showing temperate conditions."

C. W. W.

The Shelburne and South Bend Meteorites. By OLIVER CUMMINGS FARRINGTON. (Publication No. 109, Field Columbian Museum Geological Series, Vol. III, No. 2. Pp. 23, 18 plates. Chicago, 1906.)

The Shelburne, Ont., meteorite is a stony meteorite consisting of enstatite, chrysolite, and subordinate troilite and nickel—iron. The South Bend, Ind., meteorite consists of 78 per cent. chrysolite and 21 per cent. nickel-iron. The fall of the former was observed.

C. W. W.

Recent Publications

Koken, E. Geologische Beiträge aus Südtirol. [Separat-Abdruck aus dem Neuen Jahrbuch für Mineralogie, Geologie, und Paläontologie. Jahrg. 1906. Bd. II. S. 1919 und Taf. I–III. Stuttgart, 190–.]

———Productus Purdoni im Perm von Kaschmir. [Separat-Abdruck aus dem Centralblatt für Mineralogie, Geologie, und Paläontologie. Jahrg. 1906. No. 5. Stuttgart, 1906.]

—Kümmel, H. B. Annual Report of the State Geologist for the Year 1905. [Geological Survey of New Jersey. Trenton, 1906.]

—Kusakabe, S. A Note on the Direction of Earthquake Motion. [Proceedings of the Tokyo Physico-Mathematical Society, Vol. III, No. 1. February, 1906.]

———Frequency of After-Shocks and Space-Distribution of Seismic Waves. [Journal of the College of Science, Imperial University, Tokyo, Japan, Vol. XXI, Article 1. Tokyo, Japan, 1906.]

—Kunz, G. F. The Production of Precious Stones in 1905. [Extract from Mineral Resources of the United States, Calendar Year 1905. U. S. Geological Survey, Washington, 1906.]

—Lambe, F.G.S., F.R.S.C., L. M. On Amyzon brevipinne, Cope, from the Amyzon beds of the Southern Interior of British Columbia. [From the Transactions of the Royal Society of Canada. Second Series—1906–1907. Volume XII, Section IV. Ottawa, 1906.]

—Lane, A. C. Die Korngrösse der Auvergnosen. Stuttgart, 1906.

———Review of Dr. Heinrich Ries's Economic Geology of the United States. [Reprinted from Science, N. S., Vol. XXIII, No. 580, pp. 225–27, February 9, 1906.]

———The Influence of Varying Degrees of Superfusion in Magmatic Differentiation. [Journal of Canadian Mining Institute. Part of Vol. IX.]

———The Interior of the Earth. [Reprinted from Science, N. S., Vol. XXIV, No. 613, pp. 404, 405, September 28, 1906.]

———The Possibility of Deep Cracks in the Earth. [Reprint from The Michigan Miner, May, 1906.]

—Lawson, A. C. Preliminary Report of the State Earthquake Investigation Commission. Berkeley, Cal., May 31, 1906.

———The Copper Deposits of the Robinson Mining District, Nevada. [University of California Publications, Bulletin of the Department of Geology. Vol. IV, No. 14, pp. 287–357. Berkeley, May, 1906.]

———The Geomorphic Features of the Middle Kern. [University of California Publications. Bulletin of the Department of Geology, Vol. IV, No. 16, pp. 397–409, Pls. 38–41. Berkeley, September, 1906.]

———The Geomorphogeny of the Telachapi Valley System. [University of California Publications. Bulletin of the Department of Geology, Vol. IV, No. 19, pp. 431–62, Pls. 42–51. Berkeley, September, 1906.]

—LEE, W. T. Geology of the Lower Colorado River. [Bulletin of the Geological Society of America, Vol. XVII, pp. 275–84, Pls. 32–34. Rochester, June, 1906.]

———Water Resources of the Rio Grande Valley in New Mexico and Their Development. [U. S. Geological Survey. Water-Supply and Irrigation Paper No. 188. Series B, Descriptive Geology, 108. Series O, Underground Waters, 66. Washington, 1907.]

—LEITH, C. K. Iron Ore Reserves. [Reprinted from Economic Geology, Vol. I, No. 4, 1906.]

—LEVERETT, F., AND OTHERS. Flowing Wells and Municipal Water Supplies in the Middle and Northern Portions of the Southern Peninsula of Michigan. [U. S. Geological Survey. Water-Supply and Irrigation Paper No. 183. Series O, Underground Waters, 63. Washington, 1907.]

———Flowing Wells and Municipal Water Supplies in the Southern Portion of the Southern Peninsula of Michigan. [U. S. Geological Survey. Water-Supply and Irrigation Paper No. 182. Series O, Underground Waters, 62. Washington, 1906.]

—LEVERETT, F., VAUGHAN, V. C., WILLIAMS, G. S., LEIGHTON, M. O., RUSSELL, I. C. Symposium on Water Supplies in Michigan. [Reprinted from the Eighth Annual Report of the Michigan Academy of Science.]

—LEWIS, A. W. A New Illinois Oil Field. [The Mining World, April 14, 1906.]

—LEWIS, J. V. An Ontario Lead Deposit. [Reprinted from Economic Geology, Vol. I, No. 7, July–August, 1906.]

—LEWIS, S. J. Quality of Water in the Upper Ohio River Basin and at Erie, Pa. [U. S. Geological Survey. Water-Supply and Irrigation Paper No. 161. Series L, Quality of Water, 13. Washington, 1906.]

—LULL, PH.D., R. The Evolution of the Horse Family. [Yale University. Peabody Museum of Natural History, Guide No. 1. Reprinted from The American Journal of Science, Vol. XXIII, March, 1907.]

—MANSFIELD, G. R. The Origin and Structure of the Roxbury Conglomerate. [Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XLIX. Geological Series, Vol. VIII, No. 4. Cambridge, Mass., November, 1906.]

—MARR, SC.D., F.R.S., JOHN EDWARD. Address delivered at the Anniversary Meeting of the Geological Society of London, on February 16, 1906. [London, 1906.]

—McCaskey, H. D. Sixth Annual Report of the Chief of the Mining Bureau to the Honorable Secretary of the Interior, Being for the Year Ended August 31, 1905. Manila, 1906.

—McCourt, W. E. Fire Tests of Some New York Building Stones. [New York State Museum. Bulletin 100. Economic Geology 14. Albany, 1906.]

—Mead, G. H. The Teaching of Science in College. [Reprinted from Science, N. S., Vol. XXIV, No. 613, pp. 390–97, September 28, 1906.]

—Merriam, J. C. On the Occurrence of Desmostylus, Marsh. [Reprinted from Science, N. S., Vol. XXIV, No. 605, pp. 151, 152, August 3, 1906.]

———The Occurrence of Ichthyosaur-like Remains in the Upper Cretaceous of Wyoming. [Reprinted from Science, N. S., Vol. XXII, No. 568, pp. 640, 641, November 17, 1905.]

—Merrick, M.W.S.E., A. W. The Clay Slide at the Boone Viaduct, Boone, Iowa. [Western Society of Engineers, Chicago, April 4, 1906.]

—Merrill, G. P. Notes on the Composition and Structure of the Hendersonville, North Carolina, Meteorite, with Chemical Analysis by Wirt Tassin. [No. 1511. From the Proceedings of the United States National Museum, Vol. XXXII, pp. 79–82, with Pls. VIII, IX. Washington, 1907.]

———On a Newly Found Meteorite from Selma, Dallas County, Alabama. [No. 1508. From the Proceedings of the United States National Museum, Vol. XXXII, pp. 59–61, with Pls. VI, VII. Washington, 1907.]

—Mining and Geological Institute of India, Transactions of the. [Vol. I, Part 1. Calcutta, May, 1906.]

—Moritz, C.E., E. A. Tests on Reinforced Concrete Beams. [Bulletin of the University of Wisconsin, No. 148. Engineering Series, Vol. III, No. 4, pp. 319–94.]

—Mossman, F.R.S.E., R. C. Some Meteorological Results of the Scottish National Antarctic Expedition. [Reprinted from The Scottish Geographical Magazine for May, 1906. Edinburgh.]

—National Academy of Sciences, Report of the, for the Year 1906. Washington, 1907.

—Nipher, F. E. On Pressure Measurements in a Fluid Stream. [Transactions of The Academy of Science of St. Louis. Vol. XVI, No. 3.]

—Obalski, J. Mining Operations in the Province of Quebec for the Year 1905. [Department of Colonization, Mines, and Fisheries. Quebec, April, 1906.]

—Oberholsei, H. C. The North American Eagles and Their Economic Relations. [U. S. Department of Agriculture. Biological Survey-Bulletin No. 27. Washington, 1906.]

—Oldham, R. D. Constitution of the Interior of the Earth. [Quarterly Journal of the Geological Society, Vol. LXII, 1906, pp. 456–73.]

—ORTMANN, A. E. Mexican, Central American, and Cuban Cambari. [Proceedings of the Washington Academy of Sciences. Vol. VIII, pp. 1–24. Washington, May 3, 1906.]

—PARK, M. INST. M. AND M. (London), M.A. INST. M.E., F.G.S. (London), JAMES. The Geology of the Area Covered by the Alexandra Sheet, Central Otago Division. [Department of Mines, New Zealand Geological Survey. Bulletin No. 2 (New Series). Wellington, New Zealand, 1906.]

—PARR, S. W. Composition and Character of Illinois Coals. With Chapters on the Distribution of the Coal Beds of the State, by A. Bement, and Tests of Illinois Coals under Steam Boilers, by L. P. Breckenridge. [Illinois State Geological Survey. Bulletin No. 3. Urbana, 1906.]

—PENCK, A. Climatic Features of the Pleistocene Ice Age. [From The Geographic Journal for February, 1906.]

———Plan of a Map of the World—Recent Progress in the Execution of a Map of the World on the Uniform Scale of 1:1,000,000 (916 miles to the inch). [Vienna.]

—PHILIPPI, E. Die Störungen der Kreide und des Diluviums aus Jasmund und Arkona (Rügen). [Sonder-Abdruck aus Zeitschrift für Gletscherkunde. I. Band. Berlin, 1906.]

———Ueber Facettengeschiebe aus norddeutschem Diluvium. [Separat-Abdruck aus dem Neuen Jahrbuch für Mineralogie, Geologie, und Paläontologie. Jahrg. 1906. Bd. I. S. 71–80 und Taf. VIII. Stuttgart, 1906.]

—PHELPS, E. B. The Prevention of Stream Pollution by Strawboard Waste. [U. S. Geological Survey. Water-Supply and Irrigation Paper, No. 189. Series L, Quality of Water, 17. Washington, 1906.]

—PIRIE, B.Sc., M.B., J. H. H. A Note on the Geology of Gough Island. Also Notes on the Petrology of Gough Island, by R. Campbell, M.A., B.Sc. [Reprint from the Proceedings of the Royal Physical Society of Edinburgh. Session 1905–06. Vol. XVI, No. 6. Edinburgh, March, 1906.]

—PIRSSON, L. V. Samuel Lewis Penfield, 1856–96. [Am. Jour. Sci., Fourth Series, Vol. XXII, No. 131. November, 1906.]

—PLATANIA, GIOVANNE E PLATANIA, GAETANO. Sul Magnetismo Prodotto da Fulminazioni. [Estratto dalle Memorie della Classe di Scienze della R. Accademia degli Zelanti. 3*a* serie. Vol. IV. 1905–06. Acireale, 1906.]

—PRINDLE, L. M. The Yukon-Tanana Region, Alaska. Description of Circle Quadrangle. [U. S. Geological Survey, Bulletin No. 295. Series A, Economic Geology, 82. Series B, Descriptive Geology, 101. Washington, 1906.]

—PUMPELLY, R. Interdependent Evolution of Oases and Civilizations. [Bulletin of the Geological Society of America. Vol. XVII, pp. 637–70. Rochester, December, 1906.]

—RAYMOND, P. E. On the Occurrence, in the Rocky Mountains, of an Upper Devonian Fauna with Clymenia. [From The American Journal of Science, Vol. XXIII, February, 1907.]

—REID, H. F. The Flow of Glaciers and Their Stratification. [Extracted from Appalachia, Vol. XI, No. 1.]

—Réunion extraordinaire de la Société Géologique de France en Italie, à Turin et à Gênes du mardi 5 au mardi 12 septembre 1905. [Nos. 14 et 15 Compte Rendu Sommaire des Séances de la Société Géologique de France.]

—RICHARDSON, G. B. Under-Ground Water in the Valleys of Utah Lake and Jordan River, Utah. [Water-Supply and Irrigation Paper No. 157. Series B, Descriptive Geology, 86. Series O, Under-Ground Waters, 53. Washington, 1906.]

—RIES, H. The Clays of Texas. [Transactions of the American Institute of Mining Engineers. London Meeting, July, 1906. Published by permission of the director of the University of Texas Mineral Survey.]

—RIGGS, E. S. The Carapace and Plastion of Basilemys Sinuosus, a New Fossil Tortoise from the Laramie Beds of Montana. [Field Columbian Museum. Publication 110. Geological Series, Vol. II, No. 7. Chicago, February 1, 1906.]